ABSTRACT

CLEWIS, SCOTT BARTON. Economic Assessment of New Weed Management Technologies in Strip- and Conventional-Tillage Cotton and Peanut and Common Ragweed Interference in Peanut. (Under the direction of Dr. John W. Wilcut).

Low commodity prices and environmental concerns have compelled cotton growers to increase production efficiency while decreasing inputs. Research evaluated weed interference, strip-tillage production, transgenic cultivars, and new herbicides to improve weed management in peanut and cotton. The rectangular hyperbola model described the effect of common ragweed density on percent peanut yield loss. With the asymptote constrained to 100% maximum yield loss, the $I$ coefficient (yield loss per unit density as density approaches zero) was $68.3 \pm 12.2\%$. Common ragweed height was not affected by weed density or peanut canopy diameter. Weed height exceeded peanut height throughout the growing season, indicating that competition for light occurred between the two species. Common ragweed above-ground dry biomass per plant decreased as weed density increased, but total weed dry biomass per m crop row increased with weed density. Studies evaluated weed management using diclosulam and flumioxazin in strip-tillage and conventional-tillage peanut. Dimethenamid plus diclosulam or flumioxazin preemergence (PRE) controlled common lambsquarters, eclipta, and prickly sida at least 91%. Diclosulam and flumioxazin controlled Ipomoea morningglory species (59 to 91%) and bentazon plus acifluorfen postemergence (POST) provided >90% control.

Dimethenamid plus diclosulam or flumioxazin PRE produced equivalent yields and net returns with no significant differences between the two PRE options. The tillage production system did not influence weed control of eight weeds, peanut yields, or net
returns. Studies were conducted to evaluate weed management systems in non-transgenic, transgenic bromoxynil-resistant, and transgenic glyphosate-resistant cotton in strip- and conventional-tillage environments. Tillage did not affect the level of weed control provided by the herbicide systems evaluated. Excellent (>90%) control of common lambsquarters, Ipomoea species including entireleaf, ivyleaf, pitted, and tall morningglories; jimsonweed, prickly sida, and velvetleaf was achieved with programs containing bromoxynil, glyphosate, and pyrithiobac early postemergence (EPOST). Glyphosate systems controlled fall panicum, goosegrass, and large crabgrass more consistently than bromoxynil and pyrithiobac systems. Bromoxynil and pyrithiobac EPOST did not control sicklepod unless applied in mixture with MSMA and followed by (fb) a late postemergence-directed (LAYBY) treatment of prometryn plus MSMA. Herbicide systems that included glyphosate EPOST controlled sicklepod with or without a soil-applied herbicide treatment. The highest yielding systems included all the glyphosate systems and bromoxynil systems that included a soil-applied herbicide treatment. Non-transgenic systems that included a soil-applied herbicide treatment yielded less than soil-applied treatment plus glyphosate EPOST system. Net returns from glyphosate systems were generally higher than net returns from bromoxynil or pyrithiobac systems.
ECONOMIC ASSESSMENT OF NEW WEED MANAGEMENT TECHNOLOGIES IN STRIP- AND CONVENTIONAL-TILLAGE COTTON AND PEANUT AND COMMON RAGWEED INTERFERENCE IN PEANUT

by

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A thesis submitted to the Graduate Faculty of North Carolina State University in partial fulfillment of the requirements for the Degree of Master of Science

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Chair of Advisory Committee
This thesis is dedicated in to my Mother

"Without her never ending love and support, none of my accomplishments would have been possible."

Delores Ann Harrison
BIOGRAPHY

Scott B. Clewis was born in Wilmington, North Carolina on August 8, 1972. He grew in the small town of Whiteville, North Carolina. Scott graduated with honors from Whiteville High School in 1990. In December 1995, he graduated with a Bachelor of Science Degree in Microbiology and a Bachelor of Science Degree in Biology from North Carolina State University. Scott anticipates graduating in December 2001 with a Master of Science in Crop Science and a minor in Entomology from North Carolina State University.

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Scott will begin his pursuit of a Doctor of Philosophy at North Carolina State University in the spring of 2002 while continuing to serve as a research associate at North Carolina State University.
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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>LIST OF TABLES</th>
<th>vi</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF FIGURES</td>
<td>viii</td>
</tr>
<tr>
<td>LITERATURE REVIEW</td>
<td>1</td>
</tr>
<tr>
<td>COMMON RAGWEED (<em>Ambrosia artemisiifolia</em>) INTERFERENCE IN PEANUT (<em>Arachis hypogaea</em>)</td>
<td>17</td>
</tr>
<tr>
<td>Abstract</td>
<td>17</td>
</tr>
<tr>
<td>Introduction</td>
<td>18</td>
</tr>
<tr>
<td>Materials and Methods</td>
<td>19</td>
</tr>
<tr>
<td>Results and Discussion</td>
<td>23</td>
</tr>
<tr>
<td>Literature Cited</td>
<td>28</td>
</tr>
<tr>
<td>ECONOMIC ASSESSMENT OF DICLOSLULAM AND FLUMIOXAZIN IN STRIP- AND CONVENTIONAL-TILLAGE PEANUT (<em>Arachis hypogaea</em>)</td>
<td>35</td>
</tr>
<tr>
<td>Abstract</td>
<td>35</td>
</tr>
<tr>
<td>Introduction</td>
<td>36</td>
</tr>
<tr>
<td>Materials and Methods</td>
<td>38</td>
</tr>
<tr>
<td>Results and Discussion</td>
<td>42</td>
</tr>
<tr>
<td>Literature Cited</td>
<td>50</td>
</tr>
<tr>
<td>ECONOMIC ASSESSMENT OF WEED MANAGEMENT IN STRIP- AND CONVENTIONAL-TILLAGE NON-TRANSGENIC AND TRANSGENIC COTTON (<em>Gossypium hirsutum</em>)</td>
<td>68</td>
</tr>
<tr>
<td>Abstract</td>
<td>68</td>
</tr>
<tr>
<td>Introduction</td>
<td>69</td>
</tr>
<tr>
<td>Materials and Methods</td>
<td>72</td>
</tr>
<tr>
<td>Results and Discussion</td>
<td>77</td>
</tr>
<tr>
<td>Literature Cited</td>
<td>86</td>
</tr>
</tbody>
</table>
LIST OF TABLES

Economic assessment of diclosulam and flumioxazin in strip- and conventional-tillage peanut (*Arachis hypogaea*)

Table 1. Effect of preemergence and postemergence herbicide systems on peanut injury averaged over tillage systems at three North Carolina locations ........................................ 56

Table 2. Effect of preemergence and postemergence herbicide systems on yellow nutsedge and common lambsquarters control averaged over tillage systems at three North Carolina locations ........................................................................ 58

Table 3. Effect of preemergence and postemergence herbicide systems on prickly sida and pitted morningglory control averaged over tillage systems at three North Carolina locations ........................................................................ 60

Table 4. Effect of preemergence and postemergence herbicide systems on entireleaf morningglory and ivyleaf morningglory control averaged over tillage systems at two North Carolina locations ........................................................................ 62

Table 5. Effect of preemergence and postemergence herbicide systems on eclipta control at three North Carolina locations ........................................................................ 64

Table 6. Effect of preemergence and postemergence herbicide systems on peanut yield, herbicide application cost, and net economic return averaged over tillage systems at three North Carolina locations ........................................................................ 66

Economic assessment of weed management in strip- and conventional-tillage non-transgenic and transgenic cotton (*Gossypium hirsutum*)

Table 1. Average weed densities and growth stages in the nontreated control at EPOST application ........................................................................ 94

Table 2. Effect of herbicide systems on late season common lambsquarters, common ragweed, jimsonweed, and velvetleaf control averaged over location and/or years and tillage options ........................................................................ 96

Table 3. Effect of herbicide systems on late season fall panicum, large crabgrass, prickly sida, and sicklepod control averaged over location and/or years and tillage options ........................................................................ 98

Table 4. Effect of herbicide systems on late season entireleaf morningglory, ivyleaf morningglory, pitted morningglory, and tall morningglory control averaged over location and/or years and tillage options. .............................. 100
Table 5. Effect of herbicide systems on late season Palmer amaranth, sicklepod, and smooth pigweed control averaged over location and/or years and tillage options. .....102

Table 6. Effect of herbicide systems on cotton yield, economic return, and percent weed-free control averaged over location and/or years and tillage options.........................104
LIST OF FIGURES

Common ragweed (*Ambrosia artemisiifolia*) interference in peanut (*Arachis hypogaea*)

Figure 1. Relationship between common ragweed density and common ragweed dry biomass per plant for 1998 and 1999. ..........................................................33

Figure 2. Relationship between common ragweed density and incidence of late leaf spot (Florida rating scale, Chiteka et al. 1988) averaged over years.................................33

Figure 3. Relationship between common ragweed dry biomass m$^{-1}$ crop row and peanut yield. ........................................................................................................34

Figure 4. Relationship between common ragweed plant density m$^{-1}$ crop row and peanut percent yield loss, averaged over years. .........................................................34
CHAPTER 1

Literature Review

Common ragweed (*Ambrosia artemisiifolia* L.) possesses many growth characteristics that make it one of the more competitive summer annual broadleaf weeds in peanut (*Arachis hypogaea* L.). Germination and population establishment have been positively correlated with late fall and early spring soil tillage, as might be practiced with summer annual crop production (Bazzaz 1968; Keever 1950). With small plants averaging slightly more than 3,000 seeds and larger plants producing up to 62,000 seeds (Dickerson et al. 1971), common ragweed can quickly become established in the soil causing agronomic problems for years. Although several herbicides control common ragweed (Wilcut et al. 1994), it currently ranks as the third most troublesome weed in peanut in North Carolina (Dowler 1998) and infests 75% of the North Carolina-Virginia peanut production area (Bridges et al. 1994).

Common ragweed can become a dominant weed species if not controlled. Plants can rapidly grow to more than 2 m tall and intercept sunlight thus reducing productivity and yield of other plants. Interference studies conducted in North Carolina with soybeans (*Glycine max* (L.) Merr.) found that common ragweed canopy intercepted 24, 38, and 45% of the photosynthetically active radiation at 8, 10, and 12 weeks after crop emergence, respectively (Coble et. al 1981). Tall growing weeds like common ragweed may also interfere with fungicide deposition in peanut and result in increased yield loss due to foliar pathogens (Royal et al. 1997).
Failure to control common ragweed costs producers in North Carolina and Virginia an estimated $66,485,000 in peanut (Bridges et al. 1994). These losses reflect yield loss due to weed-crop interference and decreases in harvest efficiency (Wilcut et al. 1995b). Lack of registered soil-applied herbicides for common ragweed control (Wilcut and Swann 1990; Wilcut et al. 1995b) requires producers to use postemergence herbicides. The development of economic thresholds would allow producers to make informed decisions when using postemergence herbicides.

Common ragweed has been shown to be one of the most competitive weeds in crops such as white bean (*Phaseolus vulgaris* L.) (Chikoye et al. 1995) and soybeans (Coble et al. 1981) and remains a serious weed in peanut. If economic thresholds are to be utilized, data on weed interference must be collected for yield-loss prediction models (Coble and Byrd 1992). Since data on common ragweed interference with peanut has not been reported, studies were conducted to evaluate season-long interference of several common ragweed densities on peanut and common ragweed growth and productivity.

Historically, peanut have been grown as a conventionally planted crop utilizing production systems of primary and secondary tillage operations resulting in a friable, residue free, flat or slightly raised seedbed (Samples 1987). These operations require considerable fuel, labor, and time. Increasing economic inputs and concerns for declining soil organic matter, subsoil compaction, water stress damage, and sandblasting have led to interest in alternative tillage options, such as strip-tillage productions systems (Troeh et al. 1991). Strip-tillage peanut and cotton (*Gossypium hirsutum* L.) hectarage is increasing across North Carolina and the Southeastern Coastal Plain. Since peanuts are often grown in rotation with
cotton, more farmers are inclined to follow strip-till cotton with a strip-till peanut production system.

There are many advantages for utilizing strip tillage production systems including: (1) water conservation and reduction of sand blasting on sandy soils, (2) elimination of seedbed preparation reduces tillage operations and the number of trips made across the field, and (3) soil tilth and water-holding capacity are improved over time (Bradley 1995). Strip-tillage production systems work well where soils are prone to develop a hardpan or plow layer that impedes root growth or pegging (process where gynophore grows down into the soil after fertilization) (Sholar et al. 1995).

The ultimate goal is to reduce economic inputs while maintaining equivalent yields. Several studies conducted in the Southeastern United States have identified strip tillage production practices that have produced yields equivalent to conventional-till peanut (Colvin et al. 1985, 1988; Wilcut et al. 1987). However, since the late 1980’s a number of changes have occurred in herbicide options in peanut including the cancellation or withdrawal of dinoseb and naptalam registrations. Additionally, concerns about alachlor-treated peanut have eliminated this herbicide from use in U. S. peanut production (Bridges et al. 1994; Wilcut et al. 1995b). Furthermore, new registrations of herbicides since the late 1980’s include diclosulam, dimethenamid, flumioxazin, imazapic, imazethapyr, paraquat, and pyridate. Data for weed management systems for strip tillage remains limited for peanut compared with other agronomic crops (Colvin et al. 1985; Wilcut et al. 1987; Worsham 1985).
Diclosulam is a soil-applied herbicide belonging to the triazolopyrimidine sulfonanilide family developed for weed control in soybean (*Glycine max* L.) and peanut (Bailey et al. 1999a, 1999b; Barnes et al. 1998). Previous research has shown diclosulam applied PRE to control a variety of broadleaf weeds in soybean and peanut while exhibiting excellent crop tolerance (Bailey et al. 1999a, 2000; Baughman et al. 2000; Dotray et al. 2000; Main et al. 2000; Prostko et al. 1998; Sheppard et al. 1997).

Flumioxazin is an *N*-phenyl phthalimide herbicide that inhibits protoporphyrinogen oxidase (Anderson et al. 1994; Hatzios 1998; Yoshida et al. 1991). Previous research has shown flumioxazin PRE to control Florida beggarweed [*Desmodium tortuosum* (Sw.) DC], morningglories, and prickly sida in Georgia (Wilcut 1997). Flumioxazin PRE controls common lambsquarters, common ragweed (*Ambrosia artemisiifolia* L.), and jimsonweed (*Datura stramonium* L.) with good crop tolerance (Askew et al. 1999; Main et al. 2001; Wilcut et al. 2000. However, in Texas and Georgia, flumioxazin has failed to control yellow nutsedge, sicklepod [*Senna obtusifolia* (L.) Irwin and Barneby], and annual grasses consistently (Grichar and Colburn 1996; Wilcut 1997).

The recent increase in reduced-tillage peanut production on the mid-Atlantic and Southeastern Coastal Plain and the lack of data concerning weed management in reduced-tillage systems necessitates additional research. Therefore, studies were conducted to evaluate weed management systems with diclosulam and flumioxazin PRE for weed control in strip- and conventional-tillage peanut production, and to evaluate peanut response, yield potential, and economic returns to peanut in these two tillage systems.
Cotton has been grown in a conventional-tillage environment using primary and secondary tillage. Prior to the registration of POST herbicides with over-the-top selectivity in cotton, producers were required to use intensive soil-applied herbicide treatments and high use rates of relatively non-selective herbicides and specialized equipment for postemergence-directed (PDS) applications (Buchanan 1992; McWhorter and Bryson 1992; Wilcut et al. 1995a, 1997). These operations require considerable fuel, labor, and time. Increasing economic inputs, low commodity prices, and concerns for declining soil organic matter, subsoil compaction, and water stress damage have led to interest in alternative tillage options such as strip-tillage production systems (Troeh et al. 1991; Wauchope et al. 1985).

Poor weed control has been cited as the major limitation to adoption of cotton in conservation-tillage cotton production (McWhorter and Jordan 1985). Weed management in cotton often requires both soil-applied and postemergence-applied herbicides for maximum effectiveness (Buchanan 1992; Wilcut et al. 1995a). Soil-applied herbicides do not provide season-long weed control in cotton, therefore proper selection of POST herbicides and other inputs are crucial for maximum weed control, cotton yield, and economic returns (Crowley et al. 1979; Culpepper and York 1997; Wilcut et al. 1995, 1997). In the past 5 yrs, advances in biotechnology and new postemergence over-the-top (POT) technology have broaden cotton growers' options for weed management strategies (Culpepper and York 1997, 1999; Wilcut et al. 1996). Bromoxynil, glyphosate, and pyrithiobac control a broad spectrum of weeds POST (Askew and Wilcut 1999; Culpepper and York 1997, 1998, 1999; Dotray et al. 1996;
Jordan et al. 1993a; Scott et al. 2001). Bromoxynil and glyphosate can only be used in their respective transgenic herbicide-resistant cultivars (York and Culpepper 2000).


Bromoxynil controls many broadleaf weeds but does not control Palmer amaranth, sicklepod, and grasses (Culpepper and York 1997; Paulsgrove and Wilcut 2001; Paulsgrove et al. 1996). Therefore, traditional soil-applied herbicides, post-directed spray (PDS), and LAYBY herbicide treatments and or cultivation are generally required in conjunction with bromoxynil and pyrithiobac (Culpepper and York 1997, 1998; Paulsgrove and Wilcut 1999, 2001; Webster et al. 2000).

Glyphosate controls a broad spectrum of annual and perennial grass and broadleaf weeds (Wilcut and Askew 1999; Culpepper and York 1998, 1999; Wilcut et al. 1999). Glyphosate can be applied POT of glyphosate-resistant cotton from emergence through four-leaf stage. After the four-leaf stage, glyphosate should be applied PDS to minimize glyphosate contact with the cotton plant (Anonymous 1999). Since glyphosate provides no residual control, additional treatments of glyphosate PDS and or a residual LAYBY herbicide treatment are required for season-long control (Askew and Wilcut 1999; Culpepper and York 1998; Scott et al. 2001).
Previous studies have evaluated weed management with bromoxynil, glyphosate, and pyrithiobac in non-transgenic, bromoxynil-resistant, and glyphosate-resistant conventional- and no-tillage cotton environments (Askew et al. 2002; Culpepper and York 1999). The recent increase in reduced-tillage cotton production on the mid-Atlantic and Southeastern Coastal Plain and the lack of data concerning weed management in reduced-tillage systems necessitates additional research. Studies were conducted to compare weed control, cotton response and yield, and net economic returns in strip-tillage and conventional-tillage non-transgenic and transgenic cotton using pyrithiobac, bromoxynil, and glyphosate weed management systems.
Literature Cited


CHAPTER 2

Common ragweed (*Ambrosia artemisiifolia*) interference in peanut (*Arachis hypogaea*)

**Abstract**  
Studies were conducted to evaluate density-dependent effects of common ragweed on weed growth and peanut growth and yield. Common ragweed height was not affected by weed density and peanut canopy diameter. Weed height exceeded peanut height throughout the growing season, indicating that competition for light occurred between the two species. Common ragweed above-ground dry biomass per plant decreased as weed density increased, but total weed dry biomass per m crop row increased with weed density. The rectangular hyperbola model described the effect of weed density on percent peanut yield loss. With the asymptote constrained to 100% maximum yield loss, the $I$ coefficient (yield loss per unit density as density approaches zero) was $68.3 \pm 12.2\%$. Common ragweed did not influence the occurrence of tomato spotted wilt virus (TSWV), early leaf spot (*Cercospora arachidicola*), southern stem rot (*Sclerotium rolfsii*), and Cylindrocladium black rot (*Cylindrocladium crotalariae*). However, as common ragweed density increased, the incidence of late leaf spot (*Cercosporidium personatum*) increased. Results indicate that common ragweed is one of the more competitive weeds in peanut and a potential economic threat to peanut growers.

*Nomenclature: Ambrosia artemisiifolia* L. AMBEL, common ragweed; *Arachis hypogaea* L., peanut ‘NC 7’.
Key words: Competition, economic thresholds, models, peanut diameter, peanut diseases, weed biomass, weed density, weed height.

Introduction

Common ragweed (*Ambrosia artemisiifolia* L.) possesses many growth characteristics that make it one of the more competitive summer annual broadleaf weeds in peanut (*Arachis hypogaea* L.). Germination and population establishment have been positively correlated with late fall and early spring soil tillage, as might be practiced with summer annual crop production (Bazzaz 1968; Keever 1950). With small plants averaging slightly more than 3,000 seeds and larger plants producing up to 62,000 seeds (Dickerson et al. 1971), common ragweed can quickly become established in the soil causing agronomic problems for years. Although several herbicides control common ragweed (Wilcut et al. 1994), it currently ranks as the third most troublesome weed in peanut in North Carolina (Dowler 1998) and infests 75% of the North Carolina-Virginia peanut production area (Bridges et al. 1994).

Common ragweed can become a dominant weed species if not controlled. Plants can rapidly grow to more than 2 m tall and intercept sunlight thus reducing productivity and yield of other plants. Interference studies conducted in North Carolina with soybeans (*Glycine max* (L.) Merr.) found that common ragweed canopy intercepted 24, 38, and 45% of the photosynthetically active radiation at 8, 10, and 12 weeks after crop emergence, respectively (Coble et al. 1981). Tall growing weeds like common ragweed may also interfere with fungicide deposition in peanut and result in increased yield loss due to foliar pathogens (Royal et al. 1997).
Failure to control common ragweed costs producers in North Carolina and Virginia an estimated $66,485,000 in peanut (Bridges et al. 1994). These losses reflect yield loss due to weed-crop interference and decreases in harvest efficiency (Wilcut et al. 1995). Lack of registered soil-applied herbicides for common ragweed control (Wilcut and Swann 1990; Wilcut et al. 1995) requires producers to use postemergence herbicides. The development of economic thresholds would allow producers to make informed decisions when using postemergence herbicides.

Common ragweed has been shown to be one of the most competitive weeds in crops such as white bean (*Phaseolus vulgaris* L.) (Chikoye et al. 1995) and soybeans (Coble et al. 1981) and remains a serious weed in peanut. If economic threshold are to be utilized, data on weed interference must be collected for yield-loss prediction models (Coble and Byrd 1992). Since data on common ragweed interference with peanut has not been reported, studies were conducted to evaluate season-long interference of several common ragweed densities on peanut and common ragweed growth and productivity.

**Materials and Methods**

Field studies were established near Rocky Mount, NC at the Upper Coastal Plain Research Station in 1998 and 1999. Soil was a Norfolk loamy sand (fine-loamy, siliceous, thermic Typic Paleudults) with 2.1% organic matter and pH 5.1. The soil was disked and cultivated, and ethalfluralin at 0.8 kg ai ha$^{-1}$ was applied and incorporated 5 to 8 cm with a rotary tiller to control annual grasses. Ethalfluralin does not control common ragweed (Wilcut and Swann 1989; Wilcut et al. 1995). Peanut, ‘NC 7’, was planted at 134 kg ha$^{-1}$ in conventionally prepared seedbeds on May 13, 1998 and May 12, 1999.
Individual plots consisted of four rows that were 6.1 m long and spaced 96 cm apart. The experimental design was a randomized complete block with three replications.

Fertilization, insect, and disease management practices were standard for peanut production in North Carolina (Bailey 2000; Jordan 2000). Undesirable weeds were removed by hand and by early-season selective applications of acifluorfen plus bentazon at 0.28 and 0.56 kg ha\(^{-1}\), respectively. Injury to common ragweed was prevented by placing plastic cups over desirable plants prior to application. No injury was noted on common ragweed seedlings.

Immediately after peanut planting, common ragweed seedlings at the cotyledon to 2-leaf stage were transplanted 15 cm from the center two rows of each plot at 0, 1, 2, 3, 4, 8, 16, and 32 plants per 6.1 m crop row. These weed densities are equivalent to 0, 0.17, 0.34, 0.51, 0.68, 1.4, 2.7, and 5.5 plants m\(^{-1}\) of crop row. The two outer rows were left as weed-free borders. The transplanting method used in this study allowed establishment of plants with uniform size and distribution along the row (Scott et al. 2000). It is not uncommon for weeds to germinate prior to peanut planting when planting must be delayed following tillage.

Peanut and common ragweed heights were measured at 1, 2, 5, 7, 11, and 19 wk after planting in 1998 and 1, 4, 6, 8, 10, and 15 wk after planting in 1999. Height measurements were obtained by randomly selecting four common ragweed plants within each plot and measuring from the ground to the apical meristem. Peanut canopy diameter measurements were obtained by randomly selecting four plants within the center rows of each plot and measuring the diameter across the plant. At the end of the growing season,
all common ragweed plants were cut at ground level and removed from plots to facilitate peanut inversion and harvest. Common ragweed plants in all plots were actively growing at the time of their harvest. Four common ragweed plants were randomly selected from each plot and then weighed to determine average plant fresh weight and subsequently dried to determine average plant dry biomass. Peanut yield was determined by digging the middle two rows of each plot, air-drying in the field for approximately 1 wk, harvesting with a combine modified for small plot research, and weighing.

Evaluations for possible early leaf spot (Cercospora arachidicola Hori.) and late leaf spot [(Cercosporidium personatum (Berk. & Curt. Deighton)] disease incidence were taken immediately prior to harvest. The Florida rating scale (1 to 10; 1 indicates no disease and 10 indicates complete defoliation by leaf spot and dead peanut plants) was used (Chiteka et al. 1988). Visual estimates of disease incidence of tomato spotted wilt virus (TSWV) and cylindrocladium black rot (Cylindrocladium crotalariae Loos.) were taken prior to harvest as in other studies (Hau et al. 1982). Southern stem rot (Sclerotium rolfsii Sacc.) was evaluated immediately following inverting using the method of Rodriguez-Kabana et al. (1975).

Statistical Analyses

Data were tested for homogeneity of variance prior to statistical analysis by plotting residuals. Analysis of variance (ANOVA) was performed on common ragweed dry biomass, and peanut yield loss as a percentage of weed-free yield. Linear, quadratic, and higher-order polynomial effects of common ragweed density were tested by partitioning sums of squares (Draper and Smith 1981). Year was considered a random variable, and
the weed-density main effects were tested by the error associated with the appropriate year by weed-density interaction (McIntosh 1983). If significant common ragweed density effects were observed on weed dry biomass and yield loss, regression analysis was performed. Nonlinear models were used if ANOVA indicated higher-order polynomial effects of common ragweed density were more significant than linear or quadratic effects. Iterations were performed to determine parameter estimates with least sums of squares for all nonlinear models using the Gauss-Newton method via PROC NLIN in SAS (SAS 1998).

Plant height was measured at different time intervals after planting each year. Therefore, the Gompertz equation (Equation 1, Draper and Smith 1981) was fit to plant height of each species in each plot:

\[ Y_h = A e^{B e^{KT}} \]  

where \( Y_h \) is plant height in cm, \( A \) is the upper asymptote for late-season plant height, \( B \) and \( K \) are constants, \( e \) is the base of natural logarithms, and \( T \) is time in wk after planting. Multivariate analysis of variance was conducted on the three estimated parameters for each fitted curve to test for year, weed-density, and year by weed-density effects.

The relationship between common ragweed density per m of row and percent peanut yield loss was fitted to the rectangular hyperbola (Equation 2)(Cousens 1988).

\[ Y_L = \frac{(ID)}{[1 + (ID/A)]} \]  

Yield loss \( (Y_L) \) is based on a percent reduction of weed-free yield, \( A \) is the asymptote for yield loss and was constrained to 100%. \( D \) is the density per m of crop row, and \( I \) is the yield loss per weed as weed density approaches zero.
Coefficients of determination ($R^2$) were calculated for all regressions. For linear equations, $R^2$ values were calculated as 100 times the ratio of regression sums of squares to corrected total sums of squares (Askew et al. 2000; Draper and Smith 1981). Where a nonlinear equation was fit to the data, an approximate $R^2$ value, as calculated by other researchers (Askew et al. 2000; Draper and Smith 1981; Jasieniuk et al. 1999), was obtained by subtracting the ratio of residual sums of squares to corrected total sums of squares from one. The $R^2$ and residual mean squares (RMS) were used to determine goodness of fit to nonlinear models.

**Results and Discussion**

**Common Ragweed Height**

Multivariate ANOVA indicated that common ragweed height was not affected by plant density at any timing throughout the season ($P>0.05$). Average late season height was 138 and 132 cm in 1998 and 1999, respectively (data not shown). Average late season peanut diameter was 104 and 95 cm in 1998 and 1999, respectively (data not shown). Lack of intraspecific plant density effects on plant height are not uncommon (Askew et al. 1999; Askew et al. 2000; Bryson 1987; Buchanan et al. 1991; Scott et al. 2000). Regardless of common ragweed density, plants remained taller than the crop throughout the growing season (data not shown). Tall growing weeds often intercept light, thus, increasing their competitive ability. In addition, taller weeds may interfere with peanut inversion thus reducing harvesting efficiency (Young et al. 1982).

**Common Ragweed Dry Biomass**
Common ragweed above-ground dry biomass per plant decreased as common ragweed density increased (Figure 1). This relationship was best shown with a quadratic relationship in 1999 and a linear trend in 1998 (Figure 1). A quadratic relationship was used for 1999 data due to the low $R^2$ of 0.62 with a linear slope. The quadratic line had a higher $R^2$ value and the mean square error was smaller. This density-dependent decline in weed dry biomass per plant is indicative of intraspecific competition (Bridges and Chandler 1987; Rushing et al. 1985; Snipes et al. 1982). In 1998, common ragweed dry biomass per plant decreased 60 g with each additional plant per m crop row (Figure 1). In 1999, a similar decreasing trend was seen but only at the higher common ragweed densities. Average maximum biomass at the lowest plant density in 1998 and 1999 was 1150 g (dry weight) per plant, which is greater than horsenettle (*Solanum carolinense* L.) (Hackett et al. 1987), wild poinsettia (*Euphorbia heterophylla* L.) (Bridges et al. 1992), and bristly starbur (*Acanthospermum hispidum* DC.) (Walker et al. 1989), but was less than that of common cocklebur (*Xanthium strumarium* L.) in peanut (Royal et al. 1997).

**Disease Interactions**

Common ragweed did not influence the occurrence of tomato spotted wilt virus, early leaf spot, southern stem rot, and Cylindrocladium black rot (data not shown). However, as the common ragweed density increased, the incidence of late leaf spot increased (Figure 2). Common ragweed reduced deposition of foliar fungicides on peanut and may have resulted in increased disease incidence (Royal et al. 1997). In addition, large common ragweed plants shaded the peanut canopy, which may lengthen the dew period. Dew period is an important factor in disease incidence (Sherwood et al. 1995).
**Peanut Yield Loss**

Peanut yield exhibited a exponential decline as common ragweed dry biomass increased in 1998 and 1999 (Figure 3). Peanut yield decreased 1760 kg ha\(^{-1}\) with each 1 kg increase in weed biomass per m of crop row in 1998. In 1999, peanut yield decreased 1640 kg ha\(^{-1}\) with each 1 kg increase in weed biomass per m of crop row. Common cocklebur (Bridges et al. 1992) and Florida beggarweed (Buchanan et al. 1982; Hauser et al. 1982; Cardina and Brecke 1989) plant biomass was also inversely related to peanut yield. Differences between years reflect changes in peanut yield potential and common ragweed dry biomass accumulation. In 1998, maximum peanut yield was 5870 kg ha\(^{-1}\) compared to 4093 kg ha\(^{-1}\) in 1999. The slope of the exponential relationship in 1998 was steeper than in 1999. Weeds often affect crop yield more when yield potential is higher. This stability has been studied with crops such as corn (*Zea mays* L.) and soybeans (Swanton et al. 1999).

The interaction of year by common ragweed density was not significant for peanut percent yield loss, therefore the predicted curve in Figure 4 represents data averaged over both years. The hyperbolic model in Figure 4 was limited so that maximum yield loss could not exceed 100%. When the asymptotic value was constrained to 100% yield loss, as performed by other researchers (Askew et al. 1999; Jasieniuk et al. 1996; Yenish et al. 1997), the values of \(I\) and \(R^2\) were 68.3 and 0.94, respectively. However, when asymptotic iterations were not constrained values of \(I\) and \(R^2\) were 46.5 and 0.99, respectively. This decrease in the \(R^2\) value differs from other research where correlation
coefficients were not affected by asymptotic constraints (Askew et al. 1999; Jasieniuk et al. 1996; Yenish et al. 1997).

Predicted peanut yield loss from season-long interference of one common ragweed plant m\(^{-1}\) crop row was 40% (Figure 4). Maximum peanut yield loss when grown with one wild poinsettia (Bridges et al. 1992), Florida beggarweed (Cardina and Brecke 1989), and bristly starbur (Walker et al. 1989) plant m\(^{-1}\) crop was 31, 24, 16%, respectively, indicating that common ragweed is more competitive with peanut than several other common weeds. However, common ragweed was not as competitive as common cocklebur (Royal et al. 1997) which reduced peanut pod yield by 70.2% at one weed per m crop row.

The postemergence herbicide standard for common ragweed control is a commercial prepackage mixture of acifluorfen and bentazon (Wilcut et al. 1995). Using a US support price of $0.67 kg\(^{-1}\) peanut and the weed-free potential of this study (5,580 kg ha\(^{-1}\) in 1998 and 3,530 kg ha\(^{-1}\) in 1999), the density of common ragweed that would justify application of this herbicide was determined. An economic threshold based on a combined herbicide and application cost of $34.33 ha\(^{-1}\) for the prepackaged mixture of acifluorfen and bentazon would be one common ragweed plant per 115 and 80 m crop row in 1998 and 1999, respectively. These values are equivalent to 87 and 125 plants ha\(^{-1}\) in 1998 and 1999, respectively. These thresholds do not evaluate timing of weed emergence (Cousens 1987) or seed attributed to weeds (Askew et al. 1999; Sartorato et al. 1996). This study is indicative of a worse-case scenario where common ragweed emerged before the crop.
Although common ragweed plant height was not a good predictor for final weed biomass or peanut yield, a weed-crop height differential partially explained the disease incidence with peanut. Weed biomass indicated intraspecific weed competition at higher weed densities, and was inversely and linearly related to peanut pod yield. The large biomass production of common ragweed suggests that common ragweed may decrease the harvest efficiency of peanut. Tall growing broadleaf weeds like common ragweed interfere with digging and inverting of peanut during harvest operations. Additionally, common ragweed plant debris can clog or damage peanut combines (J. W. Wilcut unpublished). Research on harvesting efficiency due to weed interference has not been conducted due to the high cost of a peanut combine and the confounding of harvest data once a combine has been damaged by harvesting of weedy plots. Increased weed biomass also slows field-drying of peanut vines and pods and increases the likelihood of exposure to rainfall that may increase yield losses (Young et al. 1982; Wilcut et al. 1994). The harvesting and field drying of peanut on the Coastal Plain from Virginia to Texas occurs during the peak of hurricane season. Thus, any delays in field drying can be catastrophic in years of intense hurricane activity. Common ragweed can cause substantial peanut yield losses and appears to be more competitive than many other weeds found in peanut.
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(Solanum carolinense) with peanuts (Arachis hypogaea). Weed Sci. 35:780-784.


Figure 1. Relationship between common ragweed density and common ragweed dry biomass per plant for 1998 and 1999.

\[ y = 1.01x + 1.12 \quad R^2 = 0.95 \]

Figure 2. Relationship between common ragweed density and incidence of late leaf spot (Florida rating scale, Chiteka et al. 1988) averaged over years.

\[ y = -33x^2 + 115x + 1359 \quad R^2 = 0.94 \]

\[ y = -60x + 899 \quad R^2 = 0.97 \]
Figure 3. Relationship between common ragweed dry biomass m\(^{-1}\) crop row and peanut yield.

Figure 4. Relationship between common ragweed plant density m\(^{-1}\) crop row and peanut percent yield loss, averaged over years.
CHAPTER 3

Economic assessment of diclosulam and flumioxazin in strip- and conventional-tillage peanut (Arachis hypogaea)

Abstract Experiments were conducted in Lewiston, NC in 1999 and 2000 and Rocky Mount, NC in 1999 to evaluate weed management systems in strip- and conventional-tillage peanut. The peanut cultivars grown were ‘NC 10C’, ‘NC 12C’, and ‘NC 7’, respectively. Weed management systems consisted of different combinations of preemergence (PRE) herbicides including diclosulam and flumioxazin plus commercial postemergence (POST) herbicide systems. Dimethenamid plus diclosulam or flumioxazin PRE controlled common lambsquarters, eclipta, and prickly sida at least 91%. Diclosulam and flumioxazin provided variable control of three Ipomoea morningglory species (59 to 91%) and bentazon plus acifluorfen POST provided >90% control. Only diclosulam systems controlled yellow nutsedge 90% late season. Annual grass control required clethodim late POST, regardless of tillage system. Dimethenamid plus diclosulam or flumioxazin PRE produced equivalent yields and net returns with no significant differences between the two PRE options. Both systems produced higher yields and net returns than dimethenamid regardless of the POST herbicide option. The tillage production system did not influence weed control of eight weeds, peanut yields, or net returns. The addition of diclosulam or flumioxazin to dimethenamid PRE improved weed control compared to dimethenamid PRE alone.

Nomenclature: Acifluorfen; bentazon; clethodim; diclosulam; dimethenamid; flumioxazin; common lambsquarters, Chenopodium album L. CHEAL; eclipta, Eclipta
prostrata L. ECLAL; prickly sida, Sida spinosa L. SIDSP; yellow nutsedge, Cyperus esculentus L. CYPES; peanut, ‘NC-7’, ‘NC-10’, ‘NC-12’, Arachis hypogaea L.

Key Words: Weed management, peanut yield, and net return.

Introduction

Historically, peanuts have been grown as a conventionally planted crop utilizing production systems of primary and secondary tillage operations resulting in a friable, residue free, flat or slightly raised seedbed (Samples 1987). These operations require considerable fuel, labor, and time. Increasing economic inputs and concerns for declining soil organic matter, subsoil compaction, water stress damage, and sandblasting have led to interest in alternative tillage options, such as strip-tillage productions systems (Troeh et al. 1991). Strip-tillage peanut and cotton (Gossypium hirsutum L.) hectarage is increasing across North Carolina and the Southeastern Coastal Plain. Since peanuts are often grown in rotation with cotton, more farmers are inclined to follow strip-till cotton with a strip-till peanut production system.

There are many advantages for utilizing strip tillage production systems including: (1) water conservation and reduction of sand blasting on sandy soils, (2) elimination of seedbed preparation reduces tillage operations and the number of trips made across the field, and (3) soil tilth and water-holding capacity are improved over time (Bradley 1995). Strip-tillage production systems work well where soils are prone to develop a hardpan or plow layer that impedes root growth or pegging (process where gynophore grows down into the soil after fertilization) (Sholar et al. 1995).
The ultimate goal is to reduce economic inputs while maintaining equivalent yields. Several studies conducted in the Southeastern United States have identified strip tillage production practices that have produced yields equivalent to conventional-till peanut (Colvin et al. 1985, 1988; Wilcut et al. 1987). However, since the late 1980’s a number of changes have occurred in herbicide options in peanut including the cancellation or withdrawal of dinoseb and naptalam registrations. Additionally, concerns about alachlor-treated peanut have eliminated this herbicide from use in U. S. peanut production (Bridges et al. 1994; Wilcut et al. 1995). Furthermore, new registrations of herbicides since the late 1980’s include diclosulam, dimethenamid, flumioxazin, imazapic, imazethapyr, paraquat, and pyridate. Data for weed management systems for strip tillage remains limited for peanut compared with other agronomic crops (Colvin et al. 1985; Wilcut et al. 1987; Worsham 1985).

Diclosulam is a soil-applied herbicide belonging to the triazolopyrimidine sulfonanilide family developed for weed control in soybean (Glycine max L.) and peanut (Bailey et al. 1999a, 1999b; Barnes et al. 1998). Previous research has shown diclosulam applied PRE to control a variety of broadleaf weeds in soybean and peanut while exhibiting excellent crop tolerance (Bailey et al. 1999a, 2000; Baughman et al. 2000; Dotray et al. 2000; Main et al. 2000; Prostko et al. 1998; Sheppard et al. 1997).

Flumioxazin is an N-phenyl phthalimide herbicide that inhibits protoporphyrinogen oxidase (Anderson et al. 1994; Hatzios 1998; Yoshida et al. 1991). Previous research has shown flumioxazin PRE to control Florida beggarweed [Desmodium tortuosum (Sw.) DC], morningglories, and prickly sida in Georgia (Wilcut 1997). Flumioxazin PRE
controls common lambsquarters, common ragweed (*Ambrosia artemisiifolia* L.), and jimsonweed (*Datura stramonium* L.) with good crop tolerance (Askew et al. 1999; Main et al. 2001; Wilcut et al. 2000. However, in Texas and Georgia, flumioxazin has failed to control yellow nutsedge, sicklepod [*Senna obtusifolia* (L.) Irwin and Barneby], and annual grasses consistently (Grichar and Colburn 1996; Wilcut 1997).

The recent increase in reduced-tillage peanut production on the mid-Atlantic and Southeastern Coastal Plain and the lack of data concerning weed management in reduced-tillage systems necessitates additional research. Therefore, studies were conducted to evaluate weed management systems with diclosulam and flumioxazin PRE for weed control in strip- and conventional-tillage peanut production, and to evaluate peanut response, yield potential, and economic returns to peanut in these two tillage systems.

**Materials and Methods**

Field experiments were conducted at the Upper Coastal Plain Research Station located near Rocky Mount, NC in 1999 and at the Peanut Belt Research Station located near Lewiston-Woodville, NC in 1999 and 2000 to evaluate weed management systems in strip- and conventional-tillage peanut. Soils were a Norfolk loamy sand (fine-loamy, siliceous, thermic Typic Kandiudults) with 1.0% organic matter and pH 5.9 each year at Lewiston and a Rains fine sandy loam (fine-loamy, siliceous, thermic Typic Paleaquults) with 1.1% organic matter and pH 5.8 at Rocky Mount. These experimental sites are representative of the major peanut-producing areas of North Carolina.

Peanut cultivars included ‘NC 10C’ and ‘NC 12C’ at Lewiston, NC in 1999 and 2000 and ‘NC 7’ at Rocky Mount, NC in 1999. These cultivars are among the more widely
planted in North Carolina (Spears 2000). Peanut was planted 5 cm deep at 120 to 130 kg ha\(^{-1}\) in 91-cm rows into corn (\textit{Zea mays} L.) stubble in 1999 and into cotton stubble in 2000 at Lewiston. Peanuts were planted in wheat (\textit{Triticum aestivum} L.) at Rocky Mount in 1999. Seeding rates were typical for North Carolina according to state extension recommendations (Jordan 2000). Pest management programs other than herbicide programs were based on Cooperative Extension Service recommendations (Bailey 2000, Brandenburg 2000).

Weed species evaluated at two or more locations included broadleaf signalgrass (\textit{Brachiaria platyphylla} (Griseb.) Nash BRAPP), common lambsquarters, eclipta, entireleaf morningglory (\textit{Ipomoea hederacea} var. \textit{integriuscula} Gray), goosegrass (\textit{Eleusine indica} L. Gaertn.), ivyleaf morningglory (\textit{Ipomoea hederacea} (L.) Jacq.], large crabgrass (\textit{Digitaria sanguinalis} L. Scop.), pitted morningglory (\textit{Ipomoea lacunosa} L.), large crabgrass, prickly sida, and yellow nutsedge. At the time of early postemergence (EPOST) and POST applications, annual grass and broadleaf weeds were in the one- to seven-leaf stage while yellow nutsedge was 15 to 25 cm tall, with densities ranging from 3 to 10 plants per species m\(^{-2}\). EPOST treatments were applied 7 to 10 days after peanut emergence and POST treatments were applied approximately 2 wk after EPOST treatments. These application timings are typical of commercial postemergence systems in peanut (Wilcut 1991; Wilcut et al. 1994).

Paraquat at 0.7 kg ai ha\(^{-1}\) was applied to all plots three weeks before planting to control existing vegetation. Diclosulam was evaluated with registered preemergence PRE and POST herbicides. The PRE herbicide options included: 1) dimethenamid alone at 1.4 kg
ai ha\(^{-1}\), 2) dimethenamid plus diclosulam at 0.027 kg ai ha\(^{-1}\), 3) dimethenamid plus flumioxazin at 0.071 kg ai ha\(^{-1}\), or 4) no soil-applied herbicide treatment. Postemergence herbicide options included: 1) bentazon at 0.28 kg ai ha\(^{-1}\) plus paraquat at 0.14 kg ha\(^{-1}\) EPOST followed by a pre-packaged mixture\(^1\) of acifluorfen at 0.28 kg ai ha\(^{-1}\) plus bentazon at 0.56 kg ha\(^{-1}\) POST, 2) paraquat EPOST followed by a pre-packaged mixture of acifluorfen plus bentazon POST at the aforementioned rate, and 3) no POST herbicide treatment. A nonionic surfactant\(^2\) (NIS) at 0.25% (v/v) was included in all EPOST and POST treatments and in the paraquat burndown treatment in strip-tillage. The paraquat burndown treatments served as the untreated check for visual evaluations of weed control and crop injury. Clethodim late POST at 0.14 kg ai ha\(^{-1}\) plus crop oil concentrate\(^3\) at 1% (v/v) was needed for all treatment combinations for adequate season-long control of annual grasses including broadleaf signalgrass, goosegrass, and large crabgrass. This treatment was needed to facilitate harvest as the fibrous root systems of annual grasses interfere with digging and harvesting operations (Wilcut et al. 1994). Plot size was four 91-cm rows that were 6.1-m in length. The experimental design was a randomized complete block with each block replicated three times. A split-plot treatment arrangement with main plot tillage and subplot herbicide program was utilized to facilitate tillage and planting.

Visual estimates of weed control were recorded early (mid-June) and late in the season (late August) just prior to harvest. Weed control and peanut injury based on leaf discoloration and biomass reduction as compared to the untreated control, was visually estimated on a scale of 0 (no injury symptoms) to 100 (complete death of all plants or no
plants present) (Frans et al. 1986). Peanut injury was visually estimated 3 weeks (mid-June) after application of PRE herbicides and again 3 weeks (mid July) after POST herbicides. Weed control was visually estimated early (mid June) and late (late August) season. Since late season weed control influenced peanut yield and harvest efficiency, only late season evaluation of weed control will be presented (Wilcut et al. 1994). The center two rows of each plot were harvested in mid-October of each year using conventional harvesting equipment.

**Economic Analysis.**

An enterprise budget developed by the North Carolina Cooperative Extension Service (Brown 2000) that included operating inputs, fixed costs, and peanut yield value was modified to represent the various weed management programs. Adjustments to operating costs included crop seed, herbicide application and incorporation costs, and herbicides and adjuvant costs. The production costs included cultural and pest management procedures, equipment and labor, interest on operating equipment, harvest operations including drying and hauling, and general overhead costs. Cost of seed, herbicides, and adjuvants were based on averages of quoted prices from two local agricultural suppliers. Costs of application were $4.28 per application, based on computer models developed by the Department of Agriculture and Resource Economics at North Carolina State University. Chemical costs ha\(^{-1}\) were as follows: clethodim at $11.96 ha\(^{-1}\), crop oil concentrate at $2.35 ha\(^{-1}\), dimethenamid at $39.89 ha\(^{-1}\), bentazon at $10.10 ha\(^{-1}\), paraquat at $19.32 ha\(^{-1}\), pre-packaged mixture of acifluorfen plus bentazon at $31.62 ha\(^{-1}\), diclosulam at $54.34 ha\(^{-1}\), flumioxazin at $24.54 ha\(^{-1}\), and NIS at $1.39 ha\(^{-1}\). Herbicide system costs represent the sum of all
application, herbicide, and adjuvant costs (Table 6). Net returns were calculated by multiplying yield/ha by 100% of the price support ($0.67 kg\(^{-1}\)) and subtracting total production costs for each treatment.

**Statistical Analysis.**

Data were tested for homogeneity of variance by plotting residuals. An arcsine square-root transformation did not improve variance homogeneity, thus non-transformed data were used in analysis and presentation for clarity. Data from the non-treated control was deleted prior to analysis to stabilize variance since visually estimated weed control ratings were set to zero and peanut yield could not be harvested due to weed biomass interference with machinery. To recognize structure in the treatment arrangement, analysis of variance was conducted using the general linear models procedure in SAS (SAS 1998) to evaluate the effect of various PRE herbicide systems (four levels) and postemergence herbicide options (three levels) on crop injury, weed control, and crop yield. Sums of squares were partitioned to evaluate location and year effects that were considered separate random variables. Main effects and interactions were tested by the appropriate mean square associated with the random variables (McIntosh 1983). Mean separations were performed using Fisher’s protected LSD test at P = 0.05.

**Results and Discussion**

**Peanut Response.**

Injury at 2 weeks after planting at Lewiston 1999 was minimal with less than 8% for any PRE herbicide system. However at Rocky Mt. 1999 and Lewiston 2000, early season injury was noticeable and ranged from 0 to 25% and 0 to 15%, respectively. The
same trend in injury was evident with the POST herbicides at the three locations. Most injury was transient and amounted to 8% or less by the late injury rating (Table 1). Injury was expressed as stunting at the late evaluation. This level of stunting is not a concern with producers as excessive vine growth can lead to more disease problems and digging problems at harvest due to poor row definition (Young et al. 1982).

Weed Control.

Tillage did not influence weed control, except for eclipta, thus all weed control data excluding eclipta was pooled over tillage (Tables 2, 3, 4, and 5).

Annual grasses. When compared to non-treated plots, all herbicide treatments improved control of annual grass complex that included broadleaf signalgrass, goosegrass, large crabgrass, and Texas panicum (data not shown). Dimethenamid systems controlled these species better than systems that did not include dimethenamid. However control was 60% or less which would interfere with harvesting operations. Thus, clethodim late POST was needed for all weed management systems for adequate control (>95%) of annual grasses late season (data not shown).

Yellow nutsedge. There was a significant treatment by location interaction for yellow nutsedge control, thus data are presented separately by location. Dimethenamid PRE alone controlled yellow nutsedge 17 to 65% depending on location (Table 2). The additional use of paraquat EPOST fb acifluorfen plus bentazon POST following dimethenamid PRE increased control only at one location for dimethenamid PRE systems. The further addition of bentazon plus paraquat EPOST fb acifluorfen plus bentazon POST increased control at two locations 19 to 73 percentage points. At all
locations, yellow nutsedge control with dimethenamid plus diclosulam or flumioxazin PRE was better than control with only dimethenamid PRE. Both diclosulam and flumioxazin PRE controlled yellow nutsedge similarly. The addition of either POST system to dimethenamid plus diclosulam or flumioxazin PRE did not increase yellow nutsedge control at any location. Prostko et al. (1998) reported 83 to 87% yellow nutsedge control in conventional-tillage peanut in Texas with diclosulam PPI or PRE.

*Common lambsquarters.* There was a significant treatment by location interaction, therefore, data are presented by location. Dimethenamid PRE controlled common lambsquarters 59% or less, while dimethenamid plus diclosulam or flumioxazin PRE controlled 78 to 99% with no differences in treatments (Table 2). The additional use of either POST system to dimethenamid PRE alone increased common lambsquarters control to at least 84% at all locations. Additional use of POST systems with diclosulam and flumioxazin PRE improved control at two of the three locations. At Lewiston in 2000, common lambsquarters was controlled at least 96% with diclosulam or flumioxazin PRE. Since this level of control was so high, no further improvements in control were seen.

*Prickly sida.* There was a significant treatment by location interaction, therefore, data are presented by location. Dimethenamid PRE did not control prickly sida when compared to nontreated border areas (Table 3). However, prickly sida was controlled 100% with all other herbicide combinations at Lewiston 1999 and 2000. Prickly sida control was more variable at Rocky Mount in 1999. We attribute this variability to higher populations (10 plants per m$^2$ while populations were 2 to 3 plants per m$^2$ at the other locations).
Dimethenamid PRE did not control prickly sida, however the addition of diclosulam or flumioxazin PRE increased control to 61 and 59%, respectively. Dimethenamid PRE plus paraquat EPOST fb acifluorfen plus bentazon POST controlled prickly sida 80% compared with at least 98% control when diclosulam or flumioxazin PRE were included in the aforementioned system. A similar trend was seen with dimethenamid PRE plus bentazon plus paraquat EPOST fb acifluorfen plus bentazon POST, which controlled prickly sida 79% compared to at least 96% control with diclosulam or flumioxazin PRE in this system. It is common for season-long control of prickly sida to require two postemergence treatments (Wilcut et al. 1994).

*Pitted morningglory.* There was a significant treatment by location interaction for pitted morningglory control; thus data are presented by location. Dimethenamid PRE did not control pitted morningglory at any location while dimethenamid plus diclosulam or flumioxazin PRE controlled 59 to 89% of the populations with no differences in treatments (Table 3). Dotray et al. (2000) reported 73% control of pitted morningglory with diclosulam PRE in conventional tillage peanut. The additional use of either POST system to dimethenamid PRE alone increased pitted morningglory control 64 to 88 percentage points, depending on location. Pitted morningglory control with diclosulam and flumioxazin PRE systems was not consistently improved by additional use of POST treatments. Similar results have been seen with diclosulam PRE in conventional-tillage peanuts (Scott et al. 2001).

*Entireleaf morningglory.* Because there was a significant treatment by location for entireleaf morningglory control, data are presented separately by location. As noted with
pitted morningglory, dimethenamid PRE did not control entireleaf morningglory while
dimethenamid plus diclosulam or flumioxazin PRE controlled 80 to 90% of the
populations with no significant differences in treatments (Table 4). The addition of either
POST systems to dimethenamid PRE alone increased entireleaf morningglory control to
at 69% at all locations. Additional use of POST systems to diclosulam PRE systems
improved control at both locations while it only improved control for flumioxazin PRE
systems at Rocky Mount in 1999.

Ivyleaf morningglory. There was a significant treatment by location interaction for
ivyleaf morningglory control, therefore, data are presented by location. Many of the
trends observed with the other two morningglory species were also noted with ivyleaf
morningglory. Dimethenamid PRE did not control ivyleaf morningglory while the
addition of diclosulam or flumioxazin PRE controlled 75 to 91% of the ivyleaf
morningglory populations (Table 4). The additional use of either POST systems to
dimethenamid PRE alone improved ivyleaf morningglory control to at least 70% at both
locations. Ivyleaf morningglory control was improved with the addition of either POST
herbicide system to diclosulam or flumioxazin PRE systems at Rocky Mount in 1999 but
not at Lewiston. The level of control with diclosulam or flumioxazin PRE was so high at
Lewiston (89 to 91%), that improvements were not noted.

Eclipta. There was a significant treatment by location interaction for eclipta control,
therefore data are presented by location. Dimethenamid PRE alone did not control
eclipta at any location while dimethenamid plus diclosulam or flumioxazin PRE
controlled 86 to 98% of the eclipta populations with no differences in treatments (Table
5). The additional use of either POST system to dimethenamid PRE alone increased eclipta control 84 to 100%, depending on location. Eclipta control with diclosulam and flumioxazin PRE systems was not consistently improved by additional use of POST treatments. Similar results were reported with diclosulam applied PRE in conventional-tillage peanut in North Carolina and Texas (Bailey et al. 1999a; Prostko et al. 1998).

**Peanut Yield.**

There was a location by treatment interaction for peanut yield, thus the data is presented by location. Additionally, tillage systems did not influence peanut yield, thus yields are pooled over tillage systems. Other research has also shown a lack of yield response between reduced and conventional tillage peanut (Colvin and Brecke 1988; Colvin et al. 1988; Wilcut et al. 1987). Dimethenamid PRE treated peanut yielded 1350 to 2890 kg ha and these yields were often improved by additional inputs of diclosulam or flumioxazin PRE or by either POST herbicide system (Table 6). These increased yields reflect the increased levels of weed control provided by the additional herbicide inputs (Tables 1 to5).

These data show that diclosulam or flumioxazin PRE offers more effective broad-spectrum control of yellow nutsedge, common lambsquarters, prickly sida, eclipta, and three *Ipomoea* morningglory species than the commercial standard for North Carolina. In a majority of the comparisons, weed management systems utilizing diclosulam or flumioxazin applied PRE provided better and more consistent broadleaf weed control and higher peanut yields than weed management systems using standard POST herbicides.
Peanut yields were indicative of the level of weed management provided by diclosulam- or flumioxazin-containing systems.

**Economic Return.**

There was a location by treatment interaction for economic net returns, thus data are presented by location. Tillage did not influence economic returns, thus data are pooled over tillage systems. As with peanut yield, economic net returns from each herbicide system followed similar trends (Table 6). Systems that included dimethenamid PRE alone netted -$60 to $360 ha\(^{-1}\). Diclosulam plus dimethenamid PRE provided net returns of $380 to $2910 ha\(^{-1}\) at all locations while flumioxazin plus dimethenamid PRE resulted in net returns of $230 to $2980 ha\(^{-1}\) at all locations. The additional use of POST herbicide systems to dimethenamid PRE increased net returns in 10 of 12 comparisons with dimethenamid PRE without POST herbicides. The use of POST herbicides with diclosulam PRE or flumioxazin PRE systems increased net returns in 4 of 12 and 6 of 12 comparisons with the respective PRE systems without POST herbicides.

Early POST and POST herbicides used in this study usually increased weed control when used with dimethenamid PRE but were not always needed with diclosulam or flumioxazin PRE. Our data indicates that diclosulam and flumioxazin PRE in strip- and conventional-tillage production systems controls common lambsquarters, eclipita, and prickly sida without additional herbicide inputs. However, control of yellow nutsedge and three *Ipomoea* morningglory species frequently required additional POST herbicide treatments for season-long control. Annual grass control was inadequate and required clethodim for season-long control. The use of diclosulam or flumioxazin PRE can
improve weed control, yield, and net returns over systems of dimethenamid PRE in strip- and conventional-tillage peanut.

**Sources of Materials**

1. Storm® contains 29% sodium salt of bentazon [sodium (3-isopropyl-1-\(H\)-2, 1, 3-benzothiadiazin-4(3\(H\))-one-2, 2-dioxide)], 13% sodium salt of acifluorfen (sodium 5-[2-chloro-4-(trifluoromethyl) phenoxy]-2-nitrobenzoate, and 57% inert ingredients, manufactured by BASF Corporation, Agricultural Products Group, P.O. Box 13528, Research Triangle Park, NC 27709.

2. Induce® nonionic low-foam wetter/spreader adjuvant contains 90% nonionic surfactant (alkylarylpolyoxyalkane ether and isopropanol), free fatty acids, and 10% water, manufactured by Helena Chemical Company, Suite 500, 6075 Poplar Avenue, Memphis, TN 38137.

3. Agri-dex® contains 83% paraffin base petroleum oil and 17% surfactant blend, manufactured by Helena Chemical Company, Suite 500, 60755 Poplar Avenue, Memphis, TN 38137.
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and energy utilization. Pages 458-485 in H. E. Pattee and C. T. Young, eds., Peanut 
Science and Technology. Yoakum, TX; Am. Peanut Res. and Educ. Soc., Inc.
Table 1. Effect of preemergence and postemergence herbicide systems on peanut injury averaged over tillage systems at three North Carolina locations.\(^a\)

<table>
<thead>
<tr>
<th>Herbicides</th>
<th>Early injury</th>
<th>Late injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE(^b)</td>
<td>EPOST(^c)</td>
<td>POST(^d)</td>
</tr>
<tr>
<td>-------------------</td>
<td>--------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Dimethenamid</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Dimethenamid</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>diclosulam</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>flumioxazin</td>
<td>Paraquat</td>
<td>Acifluorfen + bentazon</td>
</tr>
<tr>
<td>Dimethenamid</td>
<td>Paraquat</td>
<td>Acifluorfen + bentazon</td>
</tr>
<tr>
<td>diclosulam</td>
<td>Paraquat</td>
<td>Acifluorfen + bentazon</td>
</tr>
<tr>
<td>flumioxazin</td>
<td>Bentazon +</td>
<td>Acifluorfen +</td>
</tr>
</tbody>
</table>
Table 1. (continued)

<table>
<thead>
<tr>
<th>Dimethenamid</th>
<th>paraquat + Bentazon + Acifluorfen +</th>
<th>6 b</th>
<th>16 c</th>
<th>15 b</th>
<th>0 a</th>
<th>0 b</th>
<th>4 abc</th>
</tr>
</thead>
<tbody>
<tr>
<td>diclosulam</td>
<td>paraquat + Bentazon + Acifluorfen +</td>
<td>8 a</td>
<td>27 b</td>
<td>16 ab</td>
<td>0 a</td>
<td>0 b</td>
<td>8 a</td>
</tr>
</tbody>
</table>

*aValues of injury within a column followed by the same letter are not significantly different at the 5% level as determined by Fisher’s Protected LSD test.*

*bThe PRE herbicide rates were dimethenamid at 1.4 kg ai ha\(^{-1}\), diclosulam at 0.027 kg ai ha\(^{-1}\), and flumioxazin at 0.071 kg ai ha\(^{-1}\).*

*cThe EPOST herbicide rates were paraquat at 0.14 kg ai ha\(^{-1}\) and bentazon at 0.28 kg ai ha\(^{-1}\) and included NIS at 0.25% (v/v).*

*dThe POST herbicide rates were acifluorfen at 0.28 kg ai ha\(^{-1}\) and bentazon at 0.56 kg ai ha\(^{-1}\) and included NIS at 0.25% (v/v).*
Table 2. Effect of preemergence and postemergence herbicide systems on yellow nutsedge and common lambsquarters control averaged over tillage systems at three North Carolina locations.\(^a\)

<table>
<thead>
<tr>
<th>Herbicides</th>
<th>Yellow nutsedge</th>
<th>Common lambsquarters</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE(^b) EPOST(^c) POST(^d)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dimethenamid</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Dimethenamid</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Dimethenamid</td>
<td>Paraquat</td>
<td>Acifluorfen + bentazon</td>
</tr>
<tr>
<td>Dimethenamid</td>
<td>Paraquat</td>
<td>Acifluorfen + bentazon</td>
</tr>
<tr>
<td>Dimethenamid</td>
<td>Paraquat</td>
<td>Acifluorfen + bentazon</td>
</tr>
<tr>
<td>Dimethenamid</td>
<td>Bentazon +</td>
<td>Acifluorfen +</td>
</tr>
</tbody>
</table>
Table 2. (continued)

<table>
<thead>
<tr>
<th>Herbicide Combination</th>
<th>paraquat</th>
<th>bentazon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimethenamid + Bentazon + Acifluorfen +</td>
<td>90 ab</td>
<td>85 a</td>
</tr>
<tr>
<td>diclosulam paraquat bentazon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dimethenamid + Bentazon + Acifluorfen +</td>
<td>88 ab</td>
<td>87 a</td>
</tr>
<tr>
<td>flumioxazin paraquat bentazon</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Values of control within a column followed by the same letter are not significantly different at the 5% level as determined by Fisher’s Protected LSD test.*

*The PRE herbicide rates were dimethenamid at 1.4 kg ai ha\(^{-1}\), diclosulam at 0.027 kg ai ha\(^{-1}\), and flumioxazin at 0.071 kg ai ha\(^{-1}\).*

*The EPOST herbicide rates were paraquat at 0.14 kg ai ha\(^{-1}\) and bentazon at 0.28 kg ai ha\(^{-1}\) and included NIS at 0.25% (v/v).*

*The POST herbicide rates were acifluorfen at 0.28 kg ai ha\(^{-1}\) and bentazon at 0.56 kg ai ha\(^{-1}\) and included NIS at 0.25% (v/v).*
Table 3. Effect of preemergence and postemergence herbicide systems on prickly sida and pitted morningglory control averaged over tillage systems at three North Carolina locations.\(^a\)

<table>
<thead>
<tr>
<th>Herbicides</th>
<th>Prickly sida</th>
<th>Pitted morningglory</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE(^b) EPOST(^c) POST(^d)</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Dimethenamid None None</td>
<td>30 b</td>
<td>0 d</td>
</tr>
<tr>
<td>Dimethenamid None None</td>
<td>100 a</td>
<td>61 c</td>
</tr>
<tr>
<td>Dimethenamid None None</td>
<td>100 a</td>
<td>59 c</td>
</tr>
<tr>
<td>Dimethenamid Paraquat</td>
<td>100 a</td>
<td>80 b</td>
</tr>
<tr>
<td>Dimethenamid Paraquat</td>
<td>100 a</td>
<td>98 a</td>
</tr>
<tr>
<td>Dimethenamid Paraquat</td>
<td>100 a</td>
<td>98 a</td>
</tr>
<tr>
<td>Dimethenamid Bentazon +</td>
<td>100 a</td>
<td>79 b</td>
</tr>
</tbody>
</table>
Table 3. (continued)

<table>
<thead>
<tr>
<th>Dimethenamid</th>
<th>paraquat</th>
<th>bentazon</th>
<th>paraquat</th>
<th>bentazon</th>
<th>paraquat</th>
<th>bentazon</th>
<th>paraquat</th>
<th>bentazon</th>
<th>paraquat</th>
<th>bentazon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bentazon +</td>
<td>Acifluorfen +</td>
<td>100 a</td>
<td>97 a</td>
<td>100 a</td>
<td>90 a</td>
<td>100 a</td>
<td>93 a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>diclosulam</td>
<td>bentazon</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bentazon +</td>
<td>Acifluorfen +</td>
<td>100 a</td>
<td>96 a</td>
<td>100 a</td>
<td>91 a</td>
<td>100 a</td>
<td>91 ab</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>flumioxazin</td>
<td>bentazon</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Values of control within a column followed by the same letter are not significantly different at the 5% level as determined by Fisher’s Protected LSD test.*

*The PRE herbicide rates were dimethenamid at 1.4 kg ai ha$^{-1}$, diclosulam at 0.027 kg ai ha$^{-1}$, and flumioxazin at 0.071 kg ai ha$^{-1}$.*

*The EPOST herbicide rates were paraquat at 0.14 kg ai ha$^{-1}$ and bentazon at 0.28 kg ai ha$^{-1}$ and included NIS at 0.25% (v/v).*

*The POST herbicide rates were acifluorfen at 0.28 kg ai ha$^{-1}$ and bentazon at 0.56 kg ai ha$^{-1}$ and included NIS at 0.25% (v/v).*
Table 4. Effect of preemergence and postemergence herbicide systems on entireleaf and ivyleaf morningglory averaged over tillage systems at three North Carolina locations.\textsuperscript{a}

<table>
<thead>
<tr>
<th>Herbicides</th>
<th>Entireleaf morningglory</th>
<th>Ivyleaf morningglory</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRE\textsuperscript{b}</td>
<td>EPOST\textsuperscript{c}</td>
<td>POST\textsuperscript{d}</td>
<td>%</td>
</tr>
<tr>
<td>Dimethenamid None</td>
<td>None</td>
<td>0 d</td>
<td>0 d</td>
</tr>
<tr>
<td>Dimethenamid + None</td>
<td>None</td>
<td>80 b</td>
<td>81 b</td>
</tr>
<tr>
<td>Dimethenamid + diclosulam</td>
<td>None</td>
<td>81 b</td>
<td>90 ab</td>
</tr>
<tr>
<td>Dimethenamid + flumioxazin</td>
<td>Paraquat Acifluorfen +</td>
<td>73 c</td>
<td>69 c</td>
</tr>
<tr>
<td></td>
<td>bentazon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dimethenamid + Paraquat</td>
<td>Acifluorfen + bentazon</td>
<td>100 a</td>
<td>93 a</td>
</tr>
<tr>
<td>Dimethenamid + diclosulam</td>
<td>Paraquat Acifluorfen +</td>
<td>100 a</td>
<td>91 ab</td>
</tr>
<tr>
<td></td>
<td>bentazon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dimethenamid + flumioxazin</td>
<td>Bentazon Acifluorfen +</td>
<td>74 bc</td>
<td>85 ab</td>
</tr>
<tr>
<td></td>
<td>bentazon</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4. (continued)

<table>
<thead>
<tr>
<th></th>
<th>paraquat</th>
<th>bentazon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimethenamid</td>
<td>Bentazon + Acifluorfen +</td>
<td>100 a 95 a 100 a 94 a</td>
</tr>
<tr>
<td>diclosulam</td>
<td>paraquat bentazon</td>
<td>100 a 95 a 100 a 94 a</td>
</tr>
<tr>
<td>Dimethenamid flumioxazin</td>
<td>paraquat bentazon</td>
<td>100 a 95 a 100 a 94 a</td>
</tr>
</tbody>
</table>

aValues of control within a column followed by the same letter are not significantly different at the 5% level as determined by Fisher’s Protected LSD test.

bThe PRE herbicide rates were dimethenamid at 1.4 kg ai ha\(^{-1}\), diclosulam at 0.027 kg ai ha\(^{-1}\), and flumioxazin at 0.071 kg ai ha\(^{-1}\).

cThe EPOST herbicide rates were paraquat at 0.14 kg ai ha\(^{-1}\) and bentazon at 0.28 kg ai ha\(^{-1}\) and included NIS at 0.25% (v/v).

dThe POST herbicide rates were acifluorfen at 0.28 kg ai ha\(^{-1}\) and bentazon at 0.56 kg ai ha\(^{-1}\) and included NIS at 0.25% (v/v).
Table 5. Effect of preemergence and postemergence herbicide systems on eclipta control at three North Carolina locations."a"

<table>
<thead>
<tr>
<th>Herbicides</th>
<th>PRE(^b)</th>
<th>EPOST(^c)</th>
<th>POST(^d)</th>
<th>Eclipta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimethenamid</td>
<td>None</td>
<td>None</td>
<td>43 d</td>
<td>40 c</td>
</tr>
<tr>
<td>Dimethenamid + diclosulam</td>
<td>None</td>
<td>None</td>
<td>86 c</td>
<td>93 ab</td>
</tr>
<tr>
<td>Dimethenamid + flumioxazin</td>
<td>None</td>
<td>None</td>
<td>89 bc</td>
<td>97 a</td>
</tr>
<tr>
<td>Dimethenamid + Paraquat + Acifluorfen + bentazon</td>
<td>95 ab</td>
<td>85 b</td>
<td>95 a</td>
<td></td>
</tr>
<tr>
<td>Dimethenamid + Paraquat + Acifluorfen + bentazon</td>
<td>98 a</td>
<td>98 a</td>
<td>100 a</td>
<td></td>
</tr>
<tr>
<td>Dimethenamid + Paraquat + Acifluorfen + bentazon</td>
<td>99 a</td>
<td>97 a</td>
<td>100 a</td>
<td></td>
</tr>
<tr>
<td>Dimethenamid + Bentazon + Acifluorfen + bentazon</td>
<td>100 a</td>
<td>84 b</td>
<td>100 a</td>
<td></td>
</tr>
</tbody>
</table>
Table 5. (continued)

<table>
<thead>
<tr>
<th>Herbicides</th>
<th>paraquat + bentazon</th>
<th>100 a</th>
<th>96 a</th>
<th>100 a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimethenamid</td>
<td>Bentazon + Acifluorfen +</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>diclosulam paraquat bentazon</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dimethenamid</td>
<td>Bentazon + Acifluorfen +</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>flumioxazin paraquat bentazon</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) Values of control within a column followed by the same letter are not significantly different at the 5% level as determined by Fisher’s Protected LSD test.

\(^b\) The PRE herbicide rates were dimethenamid at 1.4 kg ai ha\(^{-1}\), diclosulam at 0.027 kg ai ha\(^{-1}\), and flumioxazin at 0.071 kg ai ha\(^{-1}\).

\(^c\) The EPOST herbicide rates were paraquat at 0.14 kg ai ha\(^{-1}\) and bentazon at 0.28 kg ai ha\(^{-1}\) and included NIS at 0.25% (v/v).

\(^d\) The POST herbicide rates were acifluorfen at 0.28 kg ai ha\(^{-1}\) and bentazon at 0.56 kg ai ha\(^{-1}\) and included NIS at 0.25% (v/v).
Table 6. Effect of preemergence and postemergence herbicide systems peanut yield, herbicide application cost, and net economic return averaged over tillage systems at three North Carolina locations.\textsuperscript{a}

<table>
<thead>
<tr>
<th>Herbicides</th>
<th>Peanut yield</th>
<th>Economic return</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Rocky</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lewiston Mount</td>
</tr>
<tr>
<td>PRE\textsuperscript{b}</td>
<td>POST\textsuperscript{d}</td>
<td>Production cost\textsuperscript{e}</td>
</tr>
<tr>
<td>Dimethenamid None None</td>
<td>2270 d 1350 d 2890 c</td>
<td>1560</td>
</tr>
<tr>
<td>Dimethenamid None None diclosulam</td>
<td>3010 bc 5900 abc 6780 ab</td>
<td>1615</td>
</tr>
<tr>
<td>Dimethenamid None None flumioxazin</td>
<td>2730 cd 5580 bc 6830 ab</td>
<td>1585</td>
</tr>
<tr>
<td>Dimethenamid Parquat diclosulam Acifluorfen + bentazon</td>
<td>3150 bc 5750 abc 6440 b</td>
<td>1602</td>
</tr>
<tr>
<td>Dimethenamid Parquat diclosulam Acifluorfen + bentazon</td>
<td>3740 a 6130 ab 6870 ab</td>
<td>1657</td>
</tr>
<tr>
<td>Dimethenamid Parquat flumioxazin Acifluorfen + bentazon</td>
<td>3560 ab 6300 a 7150 a</td>
<td>1627</td>
</tr>
<tr>
<td>Dimethenamid Bentazon + flumioxazin Acifluorfen + bentazon</td>
<td>2740 cd 5300 c 7080 ab</td>
<td>1613</td>
</tr>
</tbody>
</table>
Table 6. (continued)

<table>
<thead>
<tr>
<th>Herbicide System</th>
<th>paraquat</th>
<th>bentazon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimethenamid</td>
<td>Bentazon + Acifluorfen +</td>
<td>3800 a</td>
</tr>
<tr>
<td>diclosulam</td>
<td>paraquat</td>
<td>bentazon</td>
</tr>
<tr>
<td>Dimethenamid</td>
<td>Bentazon + Acifluorfen +</td>
<td>3440 ab</td>
</tr>
<tr>
<td>flumioxazin</td>
<td>paraquat</td>
<td>bentazon</td>
</tr>
</tbody>
</table>

\( ^a \) Values of yield and economic return within a column followed by the same letter are not significantly different at the 5% level as determined by Fisher’s Protected LSD test.

\( ^b \) The PRE herbicide rates were dimethenamid at 1.4 kg ai ha\(^{-1}\), diclosulam at 0.027 kg ai ha\(^{-1}\), and flumioxazin at 0.071 kg ai ha\(^{-1}\).

\( ^c \) The EPOST herbicide rates were paraquat at 0.14 kg ai ha\(^{-1}\) and bentazon at 0.28 kg ai ha\(^{-1}\) and included NIS at 0.25% (v/v).

\( ^d \) The POST herbicide rates were acifluorfen at 0.28 kg ai ha\(^{-1}\) and bentazon at 0.56 kg ai ha\(^{-1}\) and included NIS at 0.25% (v/v).

\( ^e \) Application costs are calculated by summing application, herbicide cost, and adjuvant cost.

\( ^f \) Economic returns are calculated by substituting the cost and yield of each herbicide system into a farm budget (Jordan 2001).
CHAPTER 4

Economic assessment of weed management in strip- and conventional-tillage non-transgenic and transgenic cotton (*Gossypium hirsutum*)

Abstract  Studies were conducted to evaluate weed management systems in non-transgenic, transgenic bromoxynil-resistant, and transgenic glyphosate-resistant cotton in strip- and conventional-tillage environments. Tillage did not affect the level of weed control provided by the herbicide systems evaluated. Early-season stunting in strip-tillage cotton was 5% or less, regardless of herbicide system or cultivar and was transient. Excellent (>90%) control of common lambsquarters, *Ipomoea* morningglory species including entireleaf, ivyleaf, pitted, and tall morningglories; jimsonweed, prickly sida, and velvetleaf was achieved with programs containing bromoxynil, glyphosate, and pyrithiobac early postemergence (EPOST). Glyphosate systems provided better and more consistent control of fall panicum, goosegrass, and large crabgrass than bromoxynil and pyrithiobac systems. Bromoxynil and pyrithiobac EPOST did not control sicklepod unless applied in mixture with MSMA and followed by (fb) a late postemergence-directed (LAYBY) treatment of prometryn plus MSMA. Herbicide systems that included glyphosate EPOST controlled sicklepod with or without a soil-applied herbicide treatment. The highest yielding systems included all the glyphosate systems and bromoxynil systems that included a soil-applied herbicide treatment. Non-transgenic systems that included a soil-applied herbicide treatment yielded less than soil-applied treatment plus glyphosate EPOST system. Net returns from glyphosate systems were generally higher than net returns from bromoxynil or pyrithiobac systems.
**Nomenclature:** Bromoxynil; fluometuron; glyphosate; MSMA; pendimethalin; prometryn; pyrithiobac; *Abutilon theophrasti* Medicus ABUTH, velvetleaf; *Chenopodium album* L. CHEAL, common lambsquarters; *Digitaria sanguinalis* (L.) Scop. DIGSA, large crabgrass; *Eleusine indica* (L.) Gaertn. ELEIN, goosegrass; *Ipomoea hederacea* (L.) Jacq. IPOHE, ivyleaf morning glory; *Ipomoea hederacea* var. *integriuscula* Gray IPOHG, entire leaf morning glory; *Ipomoea lacunosa* L. IPOLA, pitted morning glory; *Ipomoea purpurea* L. PHBPU, tall morning glory; *Senna obtusifolia* (L.) Irwin and Barnaby CASOB, sicklepod; *G. hirsutum* L., cotton, ‘Paymaster 1220RR’, ‘Stoneville BXN 47’ and ‘Stoneville 474’.

**Key words:** Economic analysis, herbicide-resistant crops, tillage.

**Introduction**

Historically, cotton has been grown in a conventional-tillage environment using primary and secondary tillage. Prior to the registration of POST herbicides with over-the-top selectivity in cotton, producers were required to use intensive soil-applied herbicide treatments and high use rates of relatively non-selective herbicides and specialized equipment for postemergence-directed (PDS) applications (Buchanan 1992; McWhorter and Bryson 1992; Wilcut et al. 1995, 1997). These operations require considerable fuel, labor, and time. Increasing economic inputs, low commodity prices, and concerns for declining soil organic matter, subsoil compaction, and water stress damage have led to interest in alternative tillage options such as strip-tillage production systems (Troeh et al. 1991; Wauchope et al. 1985).
Strip-tillage cotton hectarage is increasing across North Carolina and the Southeastern Coastal Plain. There are several advantages for utilizing strip-tillage production systems. These advantages include: (1) water conservation and reduction of sand blasting on sandy soils, (2) elimination of seedbed preparation reduces tillage operations and the number of trips made across the field, and (3) soil tilth and water-holding capacity are improved over time (Bradley 1995). Strip-tillage production systems work well where soils are prone to develop a hardpan or plow layer that impedes root growth (Sholar et al. 1995).

Poor weed control has been cited as the major limitation to adoption of conservation-tillage in cotton production (McWhorter and Jordan 1985). Weed management in cotton often requires both soil-applied and postemergence-applied herbicides for maximum effectiveness (Buchanan 1992; Wilcut et al. 1995). Soil-applied herbicides do not provide season-long weed control in cotton, therefore proper selection of POST herbicides and other inputs are crucial for maximum weed control, cotton yield, and economic returns (Crowley et al. 1979; Culpepper and York 1997; Wilcut et al. 1995, 1997). In the past 5 yrs, advances in biotechnology and new postemergence over-the-top (POT) technology have broaden cotton growers’ options for weed management strategies (Culpepper and York 1997, 1999; Wilcut et al. 1996). Bromoxynil, glyphosate, and pyrithiobac control a broad spectrum of weeds POST (Askew and Wilcut 1999; Culpepper and York 1997, 1998, 1999; Dotray et al. 1996; Jordan et al. 1993a; Scott et al. 2001). Bromoxynil and glyphosate can only be used in their respective transgenic herbicide-resistant cultivars (York and Culpepper 2000).

Bromoxynil controls many broadleaf weeds but does not control Palmer amaranth, sicklepod, and grasses (Culpepper and York 1997; Paulsgrove and Wilcut 2001; Paulsgrove et al. 1996). Therefore, traditional soil-applied herbicides, PDS, and LAYBY herbicide treatments and or cultivation are generally required in conjunction with bromoxynil and pyritiobioc (Culpepper and York 1997, 1998; Paulsgrove and Wilcut 1999, 2001; Webster et al. 2000).

Glyphosate controls a broad spectrum of annual and perennial grass and broadleaf weeds (Wilcut and Askew 1999; Culpepper and York 1998, 1999; Wilcut et al. 1999). Glyphosate can be applied POT of glyphosate-resistant cotton from emergence through four-leaf stage. After the four-leaf stage, glyphosate should be applied PDS to minimize glyphosate contact with the cotton plant (Anonymous 1999). Glyphosate contact with cotton foliage after the 4L-growth stage of cotton can result in glyphosate accumulation in reproductive structures (Pline et al. 2001). This accumulation and the lower expression of the altered-EPSPS in male reproductive structures can cause premature fruit abortion, poor seed set, abnormalities in male reproductive structures, and sterile pollen (Jones and Snipes 1999; Pline et al. 2002a, 2002b, 2002c). Since glyphosate
provides no residual control, additional treatments of glyphosate PDS and or a residual LAYBY herbicide treatment are required for season-long control (Askew and Wilcut 1999; Culpepper and York 1998; Scott et al. 2001).

Previous studies have evaluated weed management with bromoxynil, glyphosate, and pyrithiobac in non-transgenic, bromoxynil-resistant, and glyphosate-resistant conventional- and no-tillage cotton environments (Askew et al. 2002; Culpepper and York 1999). The recent increase in reduced-tillage cotton production on the mid-Atlantic and Southeastern Coastal Plain and the lack of data concerning weed management in reduced-tillage systems necessitates additional research. Studies were conducted to compare weed control, cotton response and yield, and net economic returns in strip-tillage and conventional-tillage non-transgenic and transgenic cotton using pyrithiobac, bromoxynil, and glyphosate weed management systems.

Materials and Methods

Site Preparation

Field studies were established at the Central Crops Research Station located near Clayton, NC in 1999; the Cherry Farm Unit near Goldsboro, NC in 1999 and 2000; the Peanut Belt Research Station near Lewiston-Woodville, NC in 1999; and the Upper Coastal Plain Research Station near Rocky Mount, NC in 1999 and 2000. Soils were a Norfolk loamy sand (fine-loamy, siliceous, thermic Typic Paleudults) with 1.0% organic matter and pH 5.9 at Clayton; a Wickham loamy sand (fine-loamy, mixed, thermic Typic Hapludults) with 2.1% organic matter and pH 6.2 at Goldsboro; a Norfolk loamy sand (fine-loamy, siliceous, thermic Aquic Paleudults) with 1.1% organic matter and pH 5.9 at Lewiston-
Woodville; and a Goldsboro loamy sand (fine-loamy, siliceous, thermic Typic Paleudults) with 1.0% organic matter and pH 6.0 at Rocky Mount.

Land preparation began with desiccation of a wheat (*Triticum aestivum* L.) cover crop with glyphosate at 1.1 kg ai ha\(^{-1}\) 2 wk prior to planting. For conventionally tilled plots, soil was disked and smoothed and seed were planted with conventional equipment. In strip-tillage plots, the subsoiler shank of a Ro-Till planter with the planter units removed was utilized to open the soil and destroy plowpans beneath the rows. The fluted coulters smoothed the soil and broke up large clods. Rolling crumblers were mounted immediately behind the fluted coulters served to further smooth the seedbed. Seed were then planted using a conventional planter. Cotton cultivars, ‘Paymaster 1220RR’ (glyphosate-resistant), ‘Stoneville BNX 47’ (bromoxynil-resistant), and ‘Stoneville 474’ (non-transgenic), were planted on May 13, 1999 at Clayton, May 17, 1999 and May 25, 2000 at Goldsboro; May 10, 1999 at Lewiston; and May 11, 1999 and May 9, 2000 at Rocky Mount. Cotton was seeded at 15 seed m\(^{-1}\) of row. Plots were 7.6 m long and four 96-cm rows wide at Clayton and Goldsboro and 7.6 m long and four 91-cm wide at Rocky Mount and Lewiston.

**Experimental Design and Herbicide Programs**

*Experimental Design*

The experimental design was a randomized complete block with treatments replicated three times. A split-plot treatment arrangement with main plot tillage and subplot herbicide system was utilized to facilitate tillage and planting. Fifteen herbicide systems were evaluated in each main plot and differed between the tillage regimes. The difference
between the tillage regimes was due to the additional paraquat PRE treatment in strip-tilled cotton for control of emerged weed vegetation at planting.

**Herbicide Programs**

Five herbicide systems were evaluated in each cotton cultivar and three cultivars were grown in each tillage regime for a total of 15 herbicide systems in each tillage regime. The five herbicide systems in non-transgenic cotton included: 1) no herbicide treatment, 2) pendimethalin at 0.8 kg ai ha\(^{-1}\) plus fluometuron at 1.1 kg ai ha\(^{-1}\) PRE fb pyrithiobac at 36 g ai ha\(^{-1}\) plus MSMA at 1.1 kg ai ha\(^{-1}\) EPOST fb prometryn at 1.3 kg ai ha\(^{-1}\) plus MSMA at 2.2 kg ha\(^{-1}\) at LAYBY, 3) the aforementioned system with hand weeding as needed (ASN) to keep plot weed-free, 4) pendimethalin at 0.8 kg ha\(^{-1}\) PRE banded (46 cm wide) on the seed drill (PREBAN) fb pyrithiobac at 36 g ha\(^{-1}\) plus MSMA at 1.1 kg ha\(^{-1}\) EPOST fb pyrithiobac at 36 g ha\(^{-1}\) plus clethodim at 140 g ha\(^{-1}\) POST fb prometryn at 1.3 kg ha\(^{-1}\) plus MSMA at 2.2 kg ha\(^{-1}\) at LAYBY, and 5) pyrithiobac at 36 g ha\(^{-1}\) plus MSMA at 1.1 kg ha\(^{-1}\) EPOST fb pyrithiobac at 36 g ha\(^{-1}\) plus clethodim at 140 g ha\(^{-1}\) POST fb prometryn at 1.3 kg ha\(^{-1}\) plus MSMA at 2.2 kg ha\(^{-1}\) at LAYBY. Herbicide programs for bromoxynil-resistant cotton included: 1) no herbicide treatment, 2) pendimethalin at 0.8 kg ha\(^{-1}\) plus fluometuron at 1.1 kg ha\(^{-1}\) PRE fb bromoxynil at 0.4 kg ha\(^{-1}\) plus MSMA at 1.1 kg ha\(^{-1}\) EPOST fb prometryn at 1.3 kg ha\(^{-1}\) plus MSMA at 2.2 kg ha\(^{-1}\) at LAYBY, 3) the aforementioned system with hand weeding ASN to keep plots weed-free, 4) pendimethalin at 0.8 kg ha\(^{-1}\) PREBAN fb bromoxynil at 0.4 kg ha\(^{-1}\) plus MSMA at 1.1 kg ha\(^{-1}\) EPOST fb bromoxynil at 0.4 kg ha\(^{-1}\) plus clethodim at 140 g ha\(^{-1}\) POST fb prometryn at 1.3 kg ha\(^{-1}\) plus MSMA at 2.2 kg ha\(^{-1}\) at LAYBY, and 5)
bromoxynil at 0.4 kg ha\(^{-1}\) plus MSMA at 1.1 kg ha\(^{-1}\) EPOST fb bromoxynil 0.4 kg ha\(^{-1}\) plus clethodim at 140 g ha\(^{-1}\) POST fb prometryn at 1.3 kg ha\(^{-1}\) plus MSMA at 2.2 kg ha\(^{-1}\) at LAYBY. Herbicide programs for glyphosate-resistant cotton included: 1) no herbicide treatment, 2) pendimethalin at 0.8 kg ha\(^{-1}\) plus fluometuron at 1.1 kg ha\(^{-1}\) PRE fb glyphosate at 1.1 kg ha\(^{-1}\) EPOST fb prometryn at 1.3 kg ha\(^{-1}\) plus MSMA at 2.2 kg ha\(^{-1}\) at LAYBY, 3) the aforementioned system with hand weeding ASN to keep plots weed-free, 4) pendimethalin at 0.8 kg ha\(^{-1}\) PREBAN fb glyphosate at 1.1 kg ha\(^{-1}\) ANS fb prometryn at 1.3 kg ai ha\(^{-1}\) plus MSMA at 2.2 kg ai ha\(^{-1}\) at LAYBY, and 5) glyphosate at 1.1 kg ha\(^{-1}\) ANS fb prometryn at 1.3 kg ha\(^{-1}\) plus MSMA at 2.2 kg ha\(^{-1}\) at LAYBY.

Glyphosate ANS treatments were applied when visually estimated weed control dropped below 80% (Askew and Wilcut 1999). The number of ANS applications necessary varied from two to four depending on weed management program, weed densities, and location. In all instances, the first glyphosate ANS treatment was applied POST of two- to four-leaf cotton. Subsequent ANS treatments were applied PDS to minimize glyphosate contact with cotton foliage as specified by the glyphosate label (Anonymous 1999).

**Application Information**

Nonionic surfactant\(^1\) at 0.25% (v/v) was included with EPOST, POST, and LAYBY herbicide treatments except bromoxynil, clethodim, and glyphosate treatments. Crop oil concentrate\(^2\) at 1.0% (v/v) was included with clethodim treatments. Herbicides were applied with a compressed-CO\(_2\) sprayer calibrated to 140 L ha\(^{-1}\) at 146 kPa. Application dates were May 9 to May 25 (PRE and PREBAN), May 28 to June 25 (EPOST and
POST), and June 30 to July 10 (LAYBY) depending on location and year. Weed densities and growth stages at the EPOST application are listed in Table 1.

Data Collection

Late-season weed control, based on leaf discoloration and biomass reduction, was estimated visually on a scale of 0 to 100 where 0 = no control and 100 = death of all plants (Frans et al. 1986). Three separate injury parameters (stunting, discoloration, and stand reduction) were visually estimated for cotton 2 to 3 wk after POST treatment and late in the season using the aforementioned scale. Overall injury was also estimated as a combination of the three injury parameters. The two center rows of each plot were harvested once with a spindle picker modified for small-plot harvesting. Lint and seed yield were adjusted based on the 2-year statewide average percent lint composition of each cultivar (Bowman 1998).

Economic Analysis

An enterprise budget developed by the North Carolina Cooperative Extension Service (Brown and Cole 1997) that included operating inputs, fixed costs, and cotton yield value was modified to represent the various weed management programs. Adjustments to operating costs included crop seed and technology fees, herbicide application and incorporation costs, and herbicide and adjuvant costs. Cost of seed, technology fee, herbicides, and adjuvants were based on averages of quoted prices from two local agricultural suppliers. Planting costs including costs of seed and technology fees were $29.00 ha$^{-1}$, $44.40$ ha$^{-1}$, and $54.30$ ha$^{-1}$ for non-transgenic, bromoxynil-resistant, and glyphosate-resistant cotton, respectively. Estimated costs of POST, LAYBY, and PRE
Applications were $2.90, $5.50, and $7.80 ha\(^{-1}\), respectively, based on performance rates of machines and hourly operation costs (Anonymous 1998b). Chemical costs per ha were as follows: bromoxynil, $11.84; clethodim, $11.96; fluometuron, $9.68; glyphosate, $11.37; MSMA POST, $3.33; MSMA LAYBY, $6.66; pendimethalin, $4.67; prometryn, $10.65; pyrithiobac, $0.84; and nonionic surfactant, $1.39 ha\(^{-1}\). Crop value, based on seasonal averages of the New York Cotton Exchange minus normal discounts, was adjusted in the budget by multiplying the lint yield from each herbicide program by an estimated market price of $1.40 kg\(^{-1}\).

**Statistical Analysis**

Nontreated control plots could not be harvested due to uncontrolled weed biomass interference with machinery. The nontreated control and the weed-free checks for each variety was removed prior to analysis to improve homogeneity of variance in the weed control data. Percent data were arcsine square-root transformed to stabilize variance. Data were subjected to ANOVA and treatment sums of squares were partitioned to reflect the split-plot treatment design and year-location effects (McIntosh 1983). Where year and location effects were not significant, data were pooled. Data were analyzed separately if significant year by location effects resulted. Appropriate transformed means were separated using Fisher’s Protected LSD at \(P = 0.05\), however, non-transformed means are presented for clarity.

**Results and Discussion**
Cotton Response

Early season cotton injury for no PRE treatments was 4, 12, and 14% for glyphosate-tolerant, bromoxynil-tolerant, and non-transgenic cultivars, respectively (data not shown). This injury was indicative of early season weed pressure due to lack of soil-applied herbicide treatment. Glyphosate is a better broad-spectrum herbicide, especially on grasses, than the other two herbicides which is evident due to the lower cotton injury. Averaged over years, locations, and tillage options, EPOST herbicides did not injure cotton (data not shown) and the slight discoloration (<5%), chlorosis on the lower cotton leaves, was transient and indicative of a urea herbicide (Ahrens 1994; Anonymous 1998a). Averaged over years, locations, and tillage options, there was no significant stand reduction and therefore no differences in late-season injury among the various herbicide systems. Untreated cotton, regardless of cotton cultivar was stunted at least 80% late season (data not shown). Cotton tolerance to pyrithiobac is generally excellent unless applications are made during cold wet conditions (Allen et al. 1997; Harrison et al. 1996; Jennings et al. 1999)

Weed Control

A herbicide system main effect was observed on all weed control data, and tillage did not affect weed control (Tables 2, 3, 4, and 5). Furthermore there was no herbicide system or tillage system interaction among locations or over years. Thus all weed control data are pooled over location and year. Observed weed densities and growth stages were recorded in the non-treated plots at time of EPOST applications (Table 1).
Common lambsquarters. Common lambsquarters was controlled ≥98% with all bromoxynil- and glyphosate-containing herbicide systems and with pyrithiobac systems that used a broadcast treatment of PRE herbicides (Table 2). Bromoxynil EPOST and glyphosate EPOST control common lambsquarters (Askew and Wilcut 1999; Culpepper and York 1997; Paulsgrove and Wilcut 1999, 2001). Pyrithiobac EPOST does not control common lambsquarters (Culpepper and York 1997; Porterfield et al. 2002). Pendimethalin and fluometuron PRE and prometryn LAYBY control common lambsquarters (Paulsgrove and Wilcut 1999, 2001; Wilcut et al. 1995; York and Culpepper 2000). The lower levels of common lambsquarters control with the less intensive soil-applied herbicide systems in non-transgenic cotton, results from the lack of EPOST control from pyrithiobac and the resultant poor coverage of common lambsquarters with the LAYBY treatment of prometryn plus MSMA (data not shown).

Common ragweed. Common ragweed was controlled at least 98% with all herbicide systems (Table 2). Fluometuron PRE, prometryn LAYBY, and glyphosate and bromoxynil EPOST are effective herbicide treatments for common ragweed control (Culpepper and York 1997, 1998; York and Culpepper 2000). Pyrithiobac does not control common ragweed but does suppress it long enough to allow adequate coverage with the LAYBY treatment of prometryn plus MSMA (Paulsgrove et al. 1996).

Jimsonweed. Jimsonweed was controlled ≥98% with all weed management systems (Table 2). These levels of control are not uncommon with current registered herbicides in cotton (York and Culpepper 2000).
Velvetleaf. Glyphosate, bromoxynil, and pyrithiobac systems controlled velvetleaf at least 97% regardless of the herbicide system (Table 2). Similar results have been reported with these EPOST herbicides (Jordan et al. 1993b; Ottis et al. 2000). Prometryn LAYBY is also effective for control of velvetleaf (Jordan et al. 1997).

Fall panicum. Herbicide systems that used broadcast treatments of pendimethalin plus fluometuron PRE or glyphosate EPOST controlled fall panicum ≥98% (Table 3). Less control was provided by PREBAN systems that used bromoxynil or pyrithiobac EPOST. Glyphosate controls fall panicum and other annual grasses while bromoxynil and pyrithiobac do not (Askew and Wilcut 1999; Culpepper and York 1998; Culpepper et al. 1999; Ferriera and Coble 1984; Gimenez et al. 1998; Scott et al. 2001). Clethodim POST controls fall panicum (York and Culpepper 2000).

Goosegrass. All herbicide systems that included glyphosate EPOST, pyrithiobac EPOST, or bromoxynil EPOST that included soil-applied herbicide controlled goosegrass at least 97%. Pendimethalin, clethodim, fluometuron, glyphosate, MSMA, and prometryn control goosegrass and other annual grasses while bromoxynil and pyrithiobac do not as previously mentioned.

Large crabgrass. All glyphosate systems controlled large crabgrass at least 98% (Table 3). Most bromoxynil- and pyrithiobac-containing systems controlled less large crabgrass than glyphosate systems but control was still at least 91%. As previously mentioned, neither bromoxynil nor pyrithiobac control annual grasses like large crabgrass. Clethodim, fluometuron, glyphosate, pendimethalin, prometryn, and MSMA control annual grasses like large crabgrass (York and Culpepper 2000).
Yellow nutsedge. Yellow nutsedge was controlled at least 97% with all herbicide systems except one bromoxynil system which controlled 92% (Table 3). Pendimethalin, fluometuron, bromoxynil, and prometryn do not control yellow nutsedge. Glyphosate, MSMA, and pyrithiobac control yellow nutsedge (Wilcut et al. 1995; Wilcut 1998).

Entireleaf, ivyleaf, pitted, and tall morningglory. *Ipomoea* morningglories are not controlled adequately full-season with current registered soil-applied herbicides in cotton (Crowley et al. 1979; Culpepper and York 1997). All herbicide systems controlled the four morningglory species at least 92% with only minor differences among systems (Table 4). Although pyrithiobac controls tall morningglory less than other *Ipomoea* spp. (Sunderland et al. 1995), the plants were suppressed and controlled by the later prometryn plus MSMA LAYBY treatment (data not shown) (Paulsgrove et al. 1998). Bromoxynil, pyrithiobac, and glyphosate EPOST control *Ipomoea* morningglory species as does prometryn plus MSMA LAYBY (Askew and Wilcut 1999; Culpepper and York 1997, 1998; Webster et al. 2000). The vining growth nature of *Ipomoea* morningglories interferes with harvesting efficiency in cotton resulting in yield and fiber quality reductions (Wood et al. 1999). Thus near complete control of these weeds are desired to optimize harvesting efficiency.

Palmer amaranth. All glyphosate systems and pyrithiobac systems that used soil-applied herbicide(s) controlled Palmer amaranth ≥96% (Table 5). Less effective control was provided by pyrithiobac systems that did not use a soil-applied herbicide treatment and by all bromoxynil systems. Previous research has also shown less effective control of Palmer amaranth with bromoxynil while glyphosate and pyrithiobac are considered
effective EPOST treatments (Culpepper and York 1998; Dotray et al. 1996; Scott et al. 2001).

**Prickly sida.** Prickly sida was controlled at least 98% with all glyphosate systems and with bromoxynil and pyrithiobac systems that used a broadcast PRE soil-applied treatment (Table 5). The total POST bromoxynil and pyrithiobac systems controlled less prickly sida (87 to 91%). POST prickly sida control with bromoxynil and pyrithiobac requires timely application (Culpepper and York 1997; Paulsgrove and Wilcut 1999). Pendimethalin and fluometuron do not provide acceptable control of prickly sida (Paulsgrove and Wilcut 1999; Wilcut et al. 1988).

**Sicklepod.** Glyphosate systems controlled sicklepod at least 98% (Table 5). Bromoxynil systems controlled less sicklepod than other systems. When MSMA was included with either pyrithiobac EPOST or bromoxynil EPOST, sicklepod was stunted such that a height differential was obtained between cotton and sicklepod. This height differential allowed for more effective control by subsequent application of prometryn or MSMA LAYBY. Sicklepod control with LAYBY treatments was increased in other research when MSMA was added to bromoxynil EPOST (Paulsgrove and Wilcut 1999, 2001) and pyrithiobac EPOST (Wilcut and Hinton 1997).

**Smooth pigweed.** Glyphosate and pyrithiobac programs controlled smooth pigweed (<99%) regardless of the herbicide system (Table 5). Bromoxynil systems that did not include a broadcast PRE herbicide system were less effective for smooth pigweed control. Season-long smooth pigweed control in bromoxynil-resistant cotton requires
residual soil-applied herbicide treatment, bromoxynil EPOST, and a LAYBY treatment (Culpepper and York 1997; Scott et al. 2001).

Cotton Yield

All glyphosate herbicide systems were among the highest yielding with equivalent yields also obtained with bromoxynil and pyrithiobac systems that included the use of a soil-applied PRE herbicides (Table 6). High yields reflect high levels of weed control obtained with each herbicide system (Tables 2 to 5). Total POST herbicide systems with bromoxynil and pyrithiobac yielded less than herbicide systems that included a soil-applied herbicide treatment plus the aforementioned EPOST herbicides. Although the total POST glyphosate system yielded similarly to cotton treated with the soil-applied treatments plus glyphosate EPOST, the yield in the total POST system was 5.7% less. The lower yields in all cultivars from the total POST system reflects stunting from uncontrolled weeds due to the lack of a soil-applied herbicide treatment. Similar results have been reported for non-transgenic, transgenic bromoxynil-resistant, and transgenic glyphosate-resistant cotton (Askew and Wilcut 1999; Buchanan and Burns 1970; Culpepper and York 1999; Scott et al. 2001). Glyphosate systems that included a soil-applied herbicide treatment yielded ≥98% of the weed-free yield for the glyphosate-resistant cultivar. Equivalent protection of weed-free cotton yield was also achieved with bromoxynil EPOST plus a soil-applied herbicide treatment, and with pyrithiobac EPOST plus a broadcast PRE soil-applied treatment.
Economic Returns

Trends in net returns were similar to yield trends (Table 6). The highest net returns were obtained with all glyphosate systems. While several bromoxynil and pyrithiobac EPOST systems provided net returns equivalent to several of the glyphosate systems, they provided lower net returns than the best glyphosate system. High cotton yields and net returns were reflective of high levels of weed control (Tables 2 to 5). Total POST systems provided net returns that were statistically equivalent to the same herbicide systems with a soil-applied herbicide treatment. However total POST systems had net returns that were 11, 23, and 31% less for glyphosate, bromoxynil, and pyrithiobac systems, respectively, that included a soil-applied herbicide system. These differences reflect lower yields from early season weed interference and the increased cost of herbicide systems in the bromoxynil and pyrithiobac systems. Similar results for net returns in conventional tillage non-transgenic and transgenic cotton have been reported (Scott et al. 2001; Vencill 1998).

These data show that economically effective weed management can be obtained in both conventional- and strip-tillage cotton production environment. The registration of POST herbicides for non-transgenic and transgenic cotton has provided producers new options for broad-spectrum weed control if used in a system that includes soil-applied, EPOST, and LAYBY herbicide treatments. Glyphosate in particular, provides broad spectrum weed control, high cotton yields, and net returns while requiring minimal inputs of soil-applied herbicides. Tillage production systems did not influence weed control, yield, or net returns in non-transgenic and transgenic cotton.
Sources of Materials

1Induce® nonionic low-foam wetter/spreader adjuvant contains 90% nonionic surfactant (alkylarylpolyoxyalkane ether and isopropanol), free fatty acids, and 10% water, manufactured by Helena Chemical Company, Suite 500, 6075 Poplar Avenue, Memphis, TN 38137.

2Agri-dex® contains 83% paraffin base petroleum oil and 17% surfactant blend, manufactured by Helena Chemical Company, Suite 500, 60755 Poplar Avenue, Memphis, TN 38137.
Literature Cited


Table 1. Average weed densities and growth stages in the nontreated control at EPOST application.

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<tbody>
<tr>
<td>Common lambsquarters</td>
<td>50 (C-6L)</td>
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<td>___</td>
<td>___</td>
<td>50 (2-6L)</td>
<td>50 (2-5L)</td>
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<td>Common ragweed</td>
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<tr>
<td>Entireleaf morningglory</td>
<td>8 (C-3L)</td>
<td>___</td>
<td>___</td>
<td>___</td>
<td>6 (C-2L)</td>
<td>5 (C-3L)</td>
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<td>Fall panicum</td>
<td>34 (C-3L)</td>
<td>10 (2-4L)</td>
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<td>___</td>
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<tr>
<td>Goosegrass</td>
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<tr>
<td>Jimsonweed</td>
<td>4 (1-3L)</td>
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<td>___</td>
<td>30 (C-2L)</td>
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<td>20 (3-4L)</td>
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<td>Large crabgrass</td>
<td>50 (1-3L)</td>
<td>40 (1-3L)</td>
<td>150 (1-3L)</td>
<td>50 (2-4L)</td>
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<td>10 (1-8L)</td>
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<td>40 (C-2L)</td>
<td>100 (C-2L)</td>
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<tr>
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<td>___</td>
<td>___</td>
<td>___</td>
<td>___</td>
<td>___</td>
</tr>
<tr>
<td>Yellow nutsedge</td>
<td>___</td>
<td>___</td>
<td>___</td>
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</tr>
</tbody>
</table>

*aWeed counts were taken between May 28 and June 11 depending on location.*
<table>
<thead>
<tr>
<th>Cultivar and herbicide system&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Common lambsquarters</th>
<th>Common ragweed</th>
<th>Jimsonweed</th>
<th>Velvetleaf</th>
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<tbody>
<tr>
<td><strong>Glyphosate-resistant</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Broadcast PRE</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>99&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>99&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Banded PRE</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>99&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>No PRE</td>
<td>99&lt;sup&gt;a&lt;/sup&gt;</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>97&lt;sup&gt;b&lt;/sup&gt;</td>
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<tr>
<td><strong>Bromoxynil-resistant</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broadcast PRE</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>98&lt;sup&gt;b&lt;/sup&gt;</td>
<td>98&lt;sup&gt;b&lt;/sup&gt;</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Banded PRE</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>99&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>No PRE</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>99&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
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<td><strong>Non-transgenic</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broadcast PRE</td>
<td>99&lt;sup&gt;a&lt;/sup&gt;</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Banded PRE</td>
<td>82&lt;sup&gt;b&lt;/sup&gt;</td>
<td>99&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td>No PRE</td>
<td>53&lt;sup&gt;c&lt;/sup&gt;</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> Control averaged over locations and/or years and tillage options.
aNumbers within a column followed by the same letter are not significantly different at the 5% level as determined by Fisher’s Protected LSD test.

bCultivars were ‘Paymaster 1220 RR’ ‘Stoneville BXN 47’, and ‘Stoneville 474’ for glyphosate-resistant, bromoxynil-resistant, and non-transgenic cotton, respectively. Herbicide programs in non-transgenic cotton included: 1) pendimethalin at 0.8 kg ai ha$^{-1}$ plus fluometuron at 1.1 kg ai ha$^{-1}$ PRE fb pyrithiobac at 33 g ai ha$^{-1}$ plus MSMA at 1.1 kg ai ha$^{-1}$ EPOST, 2) pendimethalin at 0.8 kg ai ha$^{-1}$ pre-emergence banded (PREBAN) on the drill fb pyrithiobac at 33 g ai ha$^{-1}$ plus MSMA at 1.1 kg ai ha$^{-1}$ EPOST fb pyrithiobac at 33 g ai ha$^{-1}$ plus clethodim at 140 g ai ha$^{-1}$, and 3) pyrithiobac at 33 g ai ha$^{-1}$ plus MSMA at 1.1 kg ai ha$^{-1}$ EPOST fb pyrithiobac at 33 g ai ha$^{-1}$ plus clethodim at 140 g ai ha$^{-1}$ POST. Herbicide programs for bromoxynil-resistant cotton included: 1) pendimethalin at 0.8 kg ai ha$^{-1}$ plus fluometuron at 1.1 kg ai ha$^{-1}$ PRE fb bromoxynil at 0.4 kg ai ha$^{-1}$ plus MSMA at 1.1 kg ai ha$^{-1}$, 2) pendimethalin at 0.8 kg ai ha$^{-1}$ PREBAN fb bromoxynil at 0.4 kg ai ha$^{-1}$ plus MSMA at 1.1 kg ai ha$^{-1}$ EPOST fb bromoxynil at 0.4 kg ai ha$^{-1}$ plus clethodim at 140 g ai ha$^{-1}$, and 3) bromoxynil at 0.4 kg ai ha$^{-1}$ plus MSMA at 1.1 kg ai ha$^{-1}$ EPOST fb bromoxynil 0.4 kg ai ha$^{-1}$ plus clethodim at 140 g ai ha$^{-1}$ POST. Herbicide programs for glyphosate-resistant cotton included: 1) pendimethalin at 0.8 kg ai ha$^{-1}$ and fluometuron at 1.1 kg ai ha$^{-1}$ PRE fb glyphosate at 1.1 kg ai ha$^{-1}$ EPOST, 2) pendimethalin at 0.8 kg ai ha$^{-1}$ PREBAN fb glyphosate at 1.1 kg ai ha$^{-1}$ ANS (applied POT if cotton had less than five leaves and PDS if cotton had more than four leaves), and 3) glyphosate at 1.1 kg ai ha$^{-1}$ ANS. All herbicide systems included a LAYBY of prometryn at 1.3 kg ha$^{-1}$, MSMA at 2.2 kg ha$^{-1}$, and NIS at 0.25% v/v.
Table 3. Effect of herbicide systems on late season fall panicum, large crabgrass, prickly sida, and sicklepod control averaged over locations and/or years and tillage optionsa.

<table>
<thead>
<tr>
<th>Cultivar and herbicide systemb</th>
<th>Fall panicum</th>
<th>Goosegrass</th>
<th>Large crabgrass</th>
<th>Yellow nutsedge</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Glyphosate-resistant</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broadcast PRE</td>
<td>99 a</td>
<td>99 a</td>
<td>99 a</td>
<td>98 a</td>
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<tr>
<td>Banded PRE</td>
<td>100 a</td>
<td>98 a</td>
<td>99 a</td>
<td>98 a</td>
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<tr>
<td>No PRE</td>
<td>98 a</td>
<td>98 a</td>
<td>98 ab</td>
<td>95 ab</td>
</tr>
<tr>
<td><strong>Bromoxynil-resistant</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broadcast PRE</td>
<td>89 b</td>
<td>95 b</td>
<td>92 de</td>
<td>92 b</td>
</tr>
<tr>
<td>Banded PRE</td>
<td>99 a</td>
<td>98 a</td>
<td>97 abc</td>
<td>98 a</td>
</tr>
<tr>
<td>No PRE</td>
<td>98 a</td>
<td>97 ab</td>
<td>94 cde</td>
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<td><strong>Non-transgenic</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Broadcast PRE</td>
<td>87 b</td>
<td>99 a</td>
<td>91 e</td>
<td>99 a</td>
</tr>
<tr>
<td>Banded PRE</td>
<td>99 a</td>
<td>98 a</td>
<td>95 bcd</td>
<td>98 a</td>
</tr>
<tr>
<td>No PRE</td>
<td>95 a</td>
<td>98 a</td>
<td>92 e</td>
<td>97 a</td>
</tr>
</tbody>
</table>
Numbers within a column followed by the same letter are not significantly different at the 5% level as determined by Fisher’s Protected LSD test.

Cultivars were ‘Paymaster 1220 RR’, ‘Stoneville BXN 47’, and ‘Stoneville 474’ for glyphosate-resistant, bromoxynil-resistant, and non-transgenic cotton, respectively. Herbicide programs in non-transgenic cotton included: 1) pendimethalin at 0.8 kg ai ha$^{-1}$ plus fluometuron at 1.1 kg ai ha$^{-1}$ PRE fb pyrithiobac at 33 g ai ha$^{-1}$ plus MSMA at 1.1 kg ai ha$^{-1}$ EPOST, 2) pendimethalin at 0.8 kg ai ha$^{-1}$ pre-emergence banded (PREBAN) on the drill fb pyrithiobac at 33 g ai ha$^{-1}$ plus MSMA at 1.1 kg ai ha$^{-1}$ EPOST fb pyrithiobac at 33 g ai ha$^{-1}$ plus clethodim at 140 g ai ha$^{-1}$, and 3) pyrithiobac at 33 g ai ha$^{-1}$ plus MSMA at 1.1 kg ai ha$^{-1}$ EPOST fb pyrithiobac at 33 g ai ha$^{-1}$ plus clethodim at 140 g ai ha$^{-1}$ POST. Herbicide programs for bromoxynil-resistant cotton included: 1) pendimethalin at 0.8 kg ai ha$^{-1}$ plus fluometuron at 1.1 kg ai ha$^{-1}$ PRE fb bromoxynil at 0.4 kg ai ha$^{-1}$ plus MSMA at 1.1 kg ai ha$^{-1}$, 2) pendimethalin at 0.8 kg ai ha$^{-1}$ PREBAN fb bromoxynil at 0.4 kg ai ha$^{-1}$ plus MSMA at 1.1 kg ai ha$^{-1}$ EPOST fb bromoxynil at 0.4 kg ai ha$^{-1}$ plus clethodim at 140 g ai ha$^{-1}$, and 3) bromoxynil at 0.4 kg ai ha$^{-1}$ plus MSMA at 1.1 kg ai ha$^{-1}$ EPOST fb bromoxynil 0.4 kg ai ha$^{-1}$ plus clethodim at 140 g ai ha$^{-1}$ POST. Herbicide programs for glyphosate-resistant cotton included: 1) pendimethalin at 0.8 kg ai ha$^{-1}$ and fluometuron at 1.1 kg ai ha$^{-1}$ PRE fb glyphosate at 1.1 kg ai ha$^{-1}$ EPOST, 2) pendimethalin at 0.8 kg ai ha$^{-1}$ PREBAN fb glyphosate at 1.1 kg ai ha$^{-1}$ ANS (applied POT if cotton had less than five leaves and PDS if cotton had more than four leaves), and 3) glyphosate at 1.1 kg ai ha$^{-1}$ ANS. All herbicide systems included a LAYBY of prometryn at 1.3 kg ha$^{-1}$, MSMA at 2.2 kg ha$^{-1}$, and NIS at 0.25% v/v.
Table 4. Effect of herbicide systems on late season entireleaf morningglory, ivyleaf morningglory, pitted morningglory, and tall morningglory control averaged over locations and/or years and tillage options.

<table>
<thead>
<tr>
<th>Cultivar and herbicide system&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Entireleaf morningglory</th>
<th>Ivyleaf morningglory</th>
<th>Pitted morningglory</th>
<th>Tall morningglory</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Glyphosate-resistant</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>98 a</td>
<td>93 bc</td>
<td>95 b</td>
<td>99 a</td>
</tr>
<tr>
<td>Banded PRE</td>
<td>99 a</td>
<td>95 abc</td>
<td>96 ab</td>
<td>99 a</td>
</tr>
<tr>
<td>No PRE</td>
<td>98 a</td>
<td>92 c</td>
<td>96 ab</td>
<td>97 a</td>
</tr>
<tr>
<td><strong>Bromoxynil-resistant</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broadcast PRE</td>
<td>98 a</td>
<td>96 abc</td>
<td>98 ab</td>
<td>98 a</td>
</tr>
<tr>
<td>Banded PRE</td>
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<td>95 abc</td>
<td>98 ab</td>
<td>98 a</td>
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<tr>
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<td>99 a</td>
<td>99 a</td>
<td>98 ab</td>
<td>97 a</td>
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<td>98 ab</td>
<td>96 a</td>
</tr>
<tr>
<td>No PRE</td>
<td>94 b</td>
<td>98 ab</td>
<td>99 a</td>
<td>96 a</td>
</tr>
</tbody>
</table>
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Cultivars were ‘Paymaster 1220 RR’ ‘Stoneville BXN 47’, and ‘Stoneville 474’ for glyphosate-resistant, bromoxynil-resistant, and non-transgenic cotton, respectively. Herbicide programs in non-transgenic cotton included: 1) pendimethalin at 0.8 kg ai ha⁻¹ plus fluometuron at 1.1 kg ai ha⁻¹ PRE fb pyrithiobac at 33 g ai ha⁻¹ plus MSMA at 1.1 kg ai ha⁻¹ EPOST, 2) pendimethalin at 0.8 kg ai ha⁻¹ pre-emergence banded (PREBAN) on the drill fb pyrithiobac at 33 g ai ha⁻¹ plus MSMA at 1.1 kg ai ha⁻¹ EPOST fb pyrithiobac at 33 g ai ha⁻¹ plus clethodim at 140 g ai ha⁻¹, and 3) pyrithiobac at 33 g ai ha⁻¹ plus MSMA at 1.1 kg ai ha⁻¹ EPOST fb pyrithiobac at 33 g ai ha⁻¹ plus clethodim at 140 g ai ha⁻¹ EPOST. Herbicide programs for bromoxynil-resistant cotton included: 1) pendimethalin at 0.8 kg ai ha⁻¹ plus fluometuron at 1.1 kg ai ha⁻¹ PRE fb bromoxynil at 0.4 kg ai ha⁻¹ plus MSMA at 1.1 kg ai ha⁻¹, 2) pendimethalin at 0.8 kg ai ha⁻¹ PREBAN fb bromoxynil at 0.4 kg ai ha⁻¹ plus MSMA at 1.1 kg ai ha⁻¹ EPOST fb bromoxynil at 0.4 kg ai ha⁻¹ plus clethodim at 140 g ai ha⁻¹, and 3) bromoxynil at 0.4 kg ai ha⁻¹ plus MSMA at 1.1 kg ai ha⁻¹ EPOST fb bromoxynil 0.4 kg ai ha⁻¹ plus clethodim at 140 g ai ha⁻¹ EPOST. Herbicide programs for glyphosate-resistant cotton included: 1) pendimethalin at 0.8 kg ai ha⁻¹ and fluometuron at 1.1 kg ai ha⁻¹ PRE fb glyphosate at 1.1 kg ai ha⁻¹ EPOST, 2) pendimethalin at 0.8 kg ai ha⁻¹ PREBAN fb glyphosate at 1.1 kg ai ha⁻¹ ANS (applied POT if cotton had less than five leaves and PDS if cotton had more than four leaves), and 3) glyphosate at 1.1 kg ai ha⁻¹ ANS. All herbicide systems included a LAYBY of prometryn at 1.3 kg ha⁻¹, MSMA at 2.2 kg ha⁻¹, and NIS at 0.25% v/v.
Table 5. Effect of herbicide systems on late season Palmer amaranth, sicklepod, and smooth pigweed control averaged over locations and/or years and tillage options.

<table>
<thead>
<tr>
<th>Cultivar and herbicide system$^b$</th>
<th>Palmer amaranth</th>
<th>Prickly sida</th>
<th>Sicklepod</th>
<th>Smooth pigweed</th>
</tr>
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<tr>
<td><strong>Glyphosate-resistant</strong></td>
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<td>100 a</td>
<td>99 a</td>
<td>100 a</td>
<td>100 a</td>
</tr>
<tr>
<td>Banded PRE</td>
<td>100 a</td>
<td>99 a</td>
<td>100 a</td>
<td>100 a</td>
</tr>
<tr>
<td>No PRE</td>
<td>100 a</td>
<td>99 a</td>
<td>98 ab</td>
<td>99 a</td>
</tr>
<tr>
<td><strong>Bromoxynil-resistant</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broadcast PRE</td>
<td>92 b</td>
<td>98 ab</td>
<td>95 ab</td>
<td>98 a</td>
</tr>
<tr>
<td>Banded PRE</td>
<td>87 c</td>
<td>96 abc</td>
<td>87 cd</td>
<td>95 b</td>
</tr>
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<td>87 d</td>
<td>85 d</td>
<td>90 c</td>
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<td><strong>Non-transgenic</strong></td>
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<td></td>
</tr>
<tr>
<td>Broadcast PRE</td>
<td>100 a</td>
<td>98 ab</td>
<td>93 abc</td>
<td>100 a</td>
</tr>
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<td>Banded PRE</td>
<td>96 ab</td>
<td>93 bcd</td>
<td>92 bc</td>
<td>99 a</td>
</tr>
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<td>No PRE</td>
<td>92 b</td>
<td>91 cd</td>
<td>95 ab</td>
<td>99 a</td>
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</table>
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Cultivars were ‘Paymaster 1220 RR’ ‘Stoneville BXN 47’, and ‘Stoneville 474’ for glyphosate-resistant, bromoxynil-resistant, and non-transgenic cotton, respectively. Herbicide programs in non-transgenic cotton included: 1) pendimethalin at 0.8 kg ai ha\(^{-1}\) plus fluometuron at 1.1 kg ai ha\(^{-1}\) PRE fb pyrithiobac at 33 g ai ha\(^{-1}\) plus MSMA at 1.1 kg ai ha\(^{-1}\) EPOST, 2) pendimethalin at 0.8 kg ai ha\(^{-1}\) pre-emergence banded (PREBAN) on the drill fb pyrithiobac at 33 g ai ha\(^{-1}\) plus MSMA at 1.1 kg ai ha\(^{-1}\) EPOST fb pyrithiobac at 33 g ai ha\(^{-1}\) plus clethodim at 140 g ai ha\(^{-1}\), and 3) pyrithiobac at 33 g ai ha\(^{-1}\) plus MSMA at 1.1 kg ai ha\(^{-1}\) EPOST fb pyrithiobac at 33 g ai ha\(^{-1}\) plus clethodim at 140 g ai ha\(^{-1}\) POST. Herbicide programs for bromoxynil-resistant cotton included: 1) pendimethalin at 0.8 kg ai ha\(^{-1}\) plus fluometuron at 1.1 kg ai ha\(^{-1}\) PRE fb bromoxynil at 0.4 kg ai ha\(^{-1}\) plus MSMA at 1.1 kg ai ha\(^{-1}\), 2) pendimethalin at 0.8 kg ai ha\(^{-1}\) PREBAN fb bromoxynil at 0.4 kg ai ha\(^{-1}\) plus MSMA at 1.1 kg ai ha\(^{-1}\) EPOST fb bromoxynil at 0.4 kg ai ha\(^{-1}\) plus clethodim at 140 g ai ha\(^{-1}\), and 3) bromoxynil at 0.4 kg ai ha\(^{-1}\) plus MSMA at 1.1 kg ai ha\(^{-1}\) EPOST fb bromoxynil 0.4 kg ai ha\(^{-1}\) plus clethodim at 140 g ai ha\(^{-1}\) POST.

Herbicide programs for glyphosate-resistant cotton included: 1) pendimethalin at 0.8 kg ai ha\(^{-1}\) and fluometuron at 1.1 kg ai ha\(^{-1}\) PRE fb glyphosate at 1.1 kg ai ha\(^{-1}\) EPOST, 2) pendimethalin at 0.8 kg ai ha\(^{-1}\) PREBAN fb glyphosate at 1.1 kg ai ha\(^{-1}\) ANS (applied POT if cotton had less than five leaves and PDS if cotton had more than four leaves), and 3) glyphosate at 1.1 kg ai ha\(^{-1}\) ANS. All herbicide systems included a LAYBY of prometryn at 1.3 kg ha\(^{-1}\), MSMA at 2.2 kg ha\(^{-1}\), and NIS at 0.25% v/v.
Table 6. Effect of herbicide systems on cotton yield, economic return, and percent weed-free control averaged over locations and/or years and tillage options\textsuperscript{a}.

<table>
<thead>
<tr>
<th>Cultivar and herbicide system\textsuperscript{b}</th>
<th>Yield (\text{––kg ha}^{-1}\text{––} )</th>
<th>Return (\text{––} $ \text{ha}^{-1}\text{––} )</th>
<th>Weed-free yield protection (\text{––} % \text{––} )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Glyphosate-resistant</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broadcast PRE</td>
<td>1050 ( \text{a} )</td>
<td>941 ( \text{ab} )</td>
<td>99 ( \text{a} )</td>
</tr>
<tr>
<td>Banded PRE</td>
<td>1050 ( \text{a} )</td>
<td>973 ( \text{a} )</td>
<td>98 ( \text{a} )</td>
</tr>
<tr>
<td>No PRE</td>
<td>990 ( \text{ab} )</td>
<td>840 ( \text{abc} )</td>
<td>91 ( \text{ab} )</td>
</tr>
<tr>
<td><strong>Bromoxynil-resistant</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broadcast PRE</td>
<td>920 ( \text{abc} )</td>
<td>773 ( \text{bcd} )</td>
<td>94 ( \text{ab} )</td>
</tr>
<tr>
<td>Banded PRE</td>
<td>910 ( \text{abc} )</td>
<td>731 ( \text{cd} )</td>
<td>92 ( \text{ab} )</td>
</tr>
<tr>
<td>No PRE</td>
<td>810 ( \text{cd} )</td>
<td>592 ( \text{de} )</td>
<td>80 ( \text{c} )</td>
</tr>
<tr>
<td><strong>Non-transgenic</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Broadcast PRE</td>
<td>870 ( \text{bcd} )</td>
<td>676 ( \text{cd} )</td>
<td>92 ( \text{ab} )</td>
</tr>
<tr>
<td>Banded PRE</td>
<td>840 ( \text{bcd} )</td>
<td>619 ( \text{de} )</td>
<td>87 ( \text{bc} )</td>
</tr>
<tr>
<td>No PRE</td>
<td>710 ( \text{d} )</td>
<td>468 ( \text{e} )</td>
<td>69 ( \text{d} )</td>
</tr>
</tbody>
</table>

\( \text{a} \)Numbers within a column followed by the same letter are not significantly different at the 5% level as determined by Fisher’s Protected LSD test.

\( \text{b} \) Cultivars were ‘Paymaster 1220 RR’ ‘Stoneville BXN 47’, and ‘Stoneville 474’ for glyphosate-resistant, bromoxynil-resistant, and non-transgenic, respectively. Herbicide programs in non-transgenic cotton included: 1) pendimethalin at 0.8 kg ai ha\(^{-1}\) plus flumetsulam at 1.1 kg ai ha\(^{-1}\) PRE fb pyrithiobac at 33 g ai ha\(^{-1}\) plus MSMA at 1.1 kg ai ha\(^{-1}\) EPOST, 2) pendimethalin at 0.8 kg ai ha\(^{-1}\) pre-emergence banded (PREBAN) on the drill fb pyrithiobac at 33 g ai ha\(^{-1}\) plus MSMA at 1.1 kg ai ha\(^{-1}\) EPOST fb pyrithiobac at 33 g ai ha\(^{-1}\) plus clethodim at 140 g ai ha\(^{-1}\), and 3) pyrithiobac at 33 g ai ha\(^{-1}\) plus MSMA at 1.1 kg ai ha\(^{-1}\) EPOST fb pyrithiobac at 33 g ai ha\(^{-1}\) plus clethodim at 140 g ai ha\(^{-1}\) POST. Herbicide programs for bromoxynil-resistant cotton included: 1) pendimethalin
at 0.8 kg ai ha\(^{-1}\) plus fluometuron at 1.1 kg ai ha\(^{-1}\) PRE fb bromoxynil at 0.4 kg ai ha\(^{-1}\) plus MSMA at 1.1 kg ai ha\(^{-1}\), 2) pendimethalin at 0.8 kg ai ha\(^{-1}\) PREBAN fb bromoxynil at 0.4 kg ai ha\(^{-1}\) EPOST fb bromoxynil at 0.4 kg ai ha\(^{-1}\) plus clethodim at 140 g ai ha\(^{-1}\), and 3) bromoxynil at 0.4 kg ai ha\(^{-1}\) plus MSMA at 1.1 kg ai ha\(^{-1}\) EPOST fb bromoxynil 0.4 kg ai ha\(^{-1}\) plus clethodim at 140 g ai ha\(^{-1}\) POST. Herbicide programs for glyphosate-resistant cotton included: 1) pendimethalin at 0.8 kg ai ha\(^{-1}\) and fluometuron at 1.1 kg ai ha\(^{-1}\) PRE fb glyphosate at 1.1 kg ai ha\(^{-1}\) EPOST, 2) pendimethalin at 0.8 kg ai ha\(^{-1}\) PREBAN fb glyphosate at 1.1 kg ai ha\(^{-1}\) ANS (applied POT if cotton had less than five leaves and PDS if cotton had more than four leaves), and 3) glyphosate at 1.1 kg ai ha\(^{-1}\) ANS. All herbicide systems included a LAYBY of prometryn at 1.3 kg ha\(^{-1}\), MSMA at 2.2 kg ha\(^{-1}\), and NIS at 0.25% v/v.